CEMENT AND LIME MANUFACTURE

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Calcium Sulphate at High Temperatures.

As calcium sulphate is used in some works as one of the raw materials in the manufacture of Portland cement, the following notes on the behaviour of the material at high temperature are of interest. The notes are abstracted from a paper by Mr. E. S. Newman, and published by the United States National Bureau of Standards as Research Paper No. 1413.

In plants at which calcium sulphate is used as one of the raw materials for the manufacture of Portland cement, advantage is taken of the decomposition of calcium sulphate to lime, and sulphur trioxide at high temperatures. This decomposition is presumably responsible in part for the absence of $CaSO_4$ in many Portland cement clinkers made in the ordinary way. Naturally occurring calcium sulphate is found in two forms, namely, as gypsum with two molecules of water of crystallisation and as anhydrite containing no water of crystallisation. By heating gypsum at successively higher temperatures four modifications can be prepared in order as follows: (1) the hemihydrate, $CaSO_4.\frac{1}{2}H_2O$, of which plaster of paris is largely composed; (2) an extremely hygroscopic anhydrous form known as soluble anhydrite which changes rapidly to the hemihydrate in the presence of water vapour; (3) an anhydrous modification identical with the naturally occurring anhydrous calcium sulphate mentioned above; (4) and at approximately 1,200 deg. C. a high-temperature form stable, except for decomposition, only at this and higher temperatures. At such temperatures the decomposition of $CaSO_4$ to CaO and SO_3 becomes appreciable. The total equilibrium pressure of SO_3, SO_2, and O_2 over calcium sulphate has been measured and found to be approximately 100 mm. at 1,225 deg. C. The decomposition pressure increases rapidly with increase of temperature, and extrapolation of Marchal's data indicates that it probably reaches one atmosphere in the neighbourhood of 1,400 deg. C. The presence of 30 per cent. of alumina, 43 per cent. of silica, or 35 per cent. of kaolin lowers the decomposition temperature to about 1,350 deg., 1,275 deg., and 1,150

deg. C respectively. This is presumably responsible in part for the absence of calcium sulphate in many Portland cement clinkers, since the total equilibrium pressure of SO_3, SO_2, and O_2 over a mixture containing calcium sulphate, silica, and alumina may be expected to be several atmospheres at clinkering temperatures.

The transition of the ordinary forms of anhydrite to the high-temperature modification was reported to occur at 1,196 deg. C. by Gralmann who studied the material by means of a petrographic microscope equipped with a furnace for maintaining the sample at high temperatures. Abrupt changes in interference colours observed when a single crystal was heated and the appearance of the crystal on cooling served, together with heating and cooling curves, to identify a transition and fix its temperature. Masuda reported that this transition occurred at 1,232 deg. C., and unpublished data obtained by the writer indicated that the transition took place at an intermediate temperature. Because of the large variation in the reported temperature of transition, it was decided to report these data together with further studies of the behaviour of calcium sulphate at elevated temperatures and of the system CaO—$CaSO_4$.

Materials.

Artificial anhydrite, $CaSO_4$, was prepared by heating $CaSO_4.2H_2O$ of analytical reagent quality for one hour at 600 deg. C. Natural anhydrite was ground to pass a No. 200 sieve. Analyses indicated that the mineral contained 0·15 per cent. of SiO_2, 0·15 per cent. of $Al_2O_3 + Fe_2O_3$, and 0·06 per cent. of MgO. The loss on ignition was 1·6 per cent., including 0·9 per cent. of CO_2. Calcium carbonate of reagent quality was used for a source of lime in preparing mixtures of $CaSO_4$ and CaO. These mixtures were prepared by stirring the artificial anhydrite and calcium carbonate together in the desired proportions with sufficient distilled water to form a slurry, which after thorough mixing was evaporated to dryness and ground in an agate mortar to pass a No. 100 sieve. Subsequently the mixtures were ignited at 950 deg. C. for two hours to remove carbon dioxide.

Procedure.

Heating and cooling curves were obtained by means of a differential thermocouple of Pt:Pt–10-per cent. Rh in a small vertical tube furnace. The $CaSO_4$ and Al_2O_3 as the reference material were placed, respectively, in two small semicircular crucibles, $\frac{1}{2}$ in. in outside diameter and 1 in. deep, with a capacity of about 2 g. of powdered material. The two hot junctions of the differential thermocouple were embedded in the two materials and the crucibles suspended in the furnace. The e.m.f. developed by the hot junction in the $CaSO_4$ was measured by means of a precision potentiometer, and differences in temperature between the two hot junctions were indicated by the deflections of a galvanometer. The rates of heating or cooling, which were maintained constant during the series of readings taken for any one heating curve, ranged from 2 deg. to 5 deg. C. per minute. The potentiometer reading and the deflection of the galvanometer were recorded every minute, or oftener if they were changing rapidly. A few small charges wrapped in platinum foil were heated and then quenched in water or mercury. These samples were then examined by means of the petrographic

microscope and by study of their X-ray patterns. The thermocouples were calibrated by the Bureau, and the differential thermocouple was checked occasionally against the melting point of $CaO \cdot B_2O_3$ (1,154 deg. C.) and the beta-to-alpha transition of $2CaO \cdot SiO_2$ (1,420 deg. C.).

Results.

The results are given in Table 1. Examination of these data shows that the reversible transition of the ordinary form of anhydrite to the high-temperature modification occurs at approximately 1,214 deg. C. The presence of large amounts of CaO (up to 76 per cent.) did not appear to alter this temperature significantly. The temperature at which the transition occurs was further substantiated by the following procedure. Fragments of natural anhydrite were heated for ten minutes at 1,210 deg. to 1,220 deg. C., cooled, and examined. Although heating below 1,214 deg. C. caused no visual change, higher temperatures caused the particles to become opaque and under the microscope they were seen to be made up of crystallites at random orientation. The crystallites appeared to be the ordinary or beta form. Attempts to obtain alpha calcium sulphate at room temperature by quenching samples heated above the transition temperature were unsuccessful.

Another reversible thermal effect occurs on heating anhydrite to still higher temperatures. Frequently this is not found the first time the material is heated but is manifested upon cooling, and thereafter the deflections of the galvanometer become more pronounced as the heating and cooling cycles are continued. The average temperature at which this thermal effect appeared on heating artificial anhydrite was 1,371 deg. C. Natural anhydrite gave a somewhat lower value, owing perhaps to the presence of the other materials indicated by the analysis. Considerable supercooling occurs; the average temperature at which the breaks occurred in the cooling curves was 1,340 deg. and 1,329 deg. C. for the artificial and natural anhydrites respectively. This thermal effect corresponds to the inflection which Grahmann occasionally found in the cooling curve at 1,320 deg. to 1,370 deg. C.

In the present work the appearance of the contents of the crucible after heating was not uniform, but in many cases the anhydrite appeared to have fused when the temperature had at no time exceeded 1,380 deg. C. Since the temperature at which the thermal effect occurred was not greatly altered by the presence of large amounts of lime, the conclusion was drawn that it is caused by the melting and freezing of a eutectic mixture of the high-temperature form of $CaSO_4$ and CaO. The latter is produced by the decomposition of part of the $CaSO_4$, the SO_3 escaping as a gaseous product. This eutectic is probably low in CaO content, since mixtures originally containing more than 20 per cent. of CaO did not form sufficient liquid to allow the charge to present the physical appearance of having melted although, as will be seen in Table 1, the thermal effect corresponding to the melting of the eutectic was observed. On the other hand, samples originally consisting of pure $CaSO_4$ appeared to have melted when analyses showed that only from 4 to 12 per cent. of CaO had been formed. Attempts to obtain segments of the liquidus curve failed since no further heat effects were observed in any experiment between the

TABLE I.—TEMPERATURE OF ALPHA-BETA TRANSITION AND OF EUTECTIC MELTING OBSERVED WITH CALCIUM SULPHATE AND WITH CALCIUM SULPHATE-LIME MIXTURES.

Natural anhydrite [a]				Artificial anhydrite [b]				Calcium sulfate-lime mixtures [c]					
Transition temperature		Eutectic temperature		Transition temperature		Eutectic temperature		CaO [d]	Transition temperature		Eutectic temperature		CaO after heating
From heating curves	From cooling curves	From heating curves	From cooling curves	From heating curves	From cooling curves	From heating curves	From cooling curves		From heating curves	From cooling curves	From heating curves	From cooling curves	
°C	°C	°C	°C	°C	°C	°C	°C	%	°C	°C	°C	°C	%
1,213	1,193	1,345	1,314	1,216	1,198	1,367	1,338	12	1,217	(e)	1,371	1,350	20
1,215	1,214	1,360	1,333	1,220	1,196	1,371	1,346	17	1,213	(e)	1,362	(e)	(e)
1,214	1,201	1,359	1,328	1,214	1,196	1,375	1,348	29	1,213	1,202	1,369	1,349	35
1,212	1,199	1,350	1,327	1,213	1,193	1,356	1,348	45	1,214	(e)	1,364	(e)	55
1,211	1,207	1,348	1,323	1,215	1,214	1,371	1,327	76	1,219	1,202	1,351	1,337	83
1,215	1,205	1,367	1,350	1,214	1,200	1,376	1,332	93	(f)	(f)	(f)	(f)	100
1,215	1,203	1,384	----------	1,216	1,196	1,377	1,342	----------	----------	----------	----------	----------	----------
1,217	1,202	----------	----------	1,216	1,199	1,377	1,341	----------	----------	----------	----------	----------	----------
1,214	1,198	----------	----------	1,212	----------	1,367	1,338	----------	----------	----------	----------	----------	----------
1,209	1,202	----------	----------	1,214	----------	----------	1,336	----------	----------	----------	----------	----------	----------
1,216	----------	----------	----------	----------	----------	----------	1,345	----------	----------	----------	----------	----------	----------
Average..1,214	1,202	1,359	1,329	1,215	1,199	1,371	1,340	----------	1,215	1,202	1,363	1,345	----------

[a] From Midland, Calif.
R_2O_3+MgO+SiO_2=0.5 percent;
loss on ignition=1.6 percent.
[b] Prepared by heating $CaSO_4.2H_2O$ of analytical reagent quality for 1 hour at 600° C.
[c] Prepared by heating mixtures of artificial anhydrite (footnote b) and calcium carbonate of reagent quality.
[d] Original composition, calculated.
[e] Not determined.
[f] Not observed, insufficient $CaSO_4$ in mixture to give observable deflection of galvanometer.

melting of the eutectic and the limit of the furnace, 1,545 deg. C. This was presumably due to the decomposition of the $CaSO_4$, which, on the assumption that the eutectic is low in lime, would have shifted the composition in the direction of high-melting mixtures. It is apparent that a closed apparatus must be used in a precise study of this system. However, it is interesting to note that Grahmann, using a 20-g. sample of $CaSO_4$, observed melting at 1,450 deg. C., and reported this value as the melting point of pure $CaSO_4$. On the basis of this investigation Grahmann's result may be interpreted as representing a point on the liquidus curve, the true melting point being higher.

Although compounds of CaO and SO_3 corresponding to the formulæ $2CaO{\cdot}SO_3$ and $3CaO{\cdot}2CaSO_4$ have been reported, their existence was not confirmed in the present work. X-ray patterns were prepared of samples of both natural and artificial anhydrites quenched from temperatures ranging from 1,200 deg. to 1,545 deg. C. and of mixtures of anhydrite and CaO quenched from temperatures between 1,300 deg. and 1,545 deg. C. In only two cases were lines found in the X-ray patterns that did not correspond with lines in the patterns of anhydrite, CaO or $Ca(OH)_2$ (in samples quenched in water or partly hydrated by atmospheric moisture). Two samples of a mixture originally of the proportions $2CaO{\cdot}1SO_3$ were quenched, one from 1,390 deg. C. and the other from 1,545 deg. C. On the corresponding X-ray patterns fairly strong lines were found at a position corresponding to an interplanar spacing of 2·12 A and weak lines were found at 0·942 A. In the patterns of other similar mixtures quenched from similar temperatures, no such lines were observed and, in every pattern obtained, all (or all but the weakest) lines of the ordinary form of anhydrite were found.

To summarise, the transition of beta calcium sulphate to alpha calcium sulphate occurs at approximately 1,214 deg. C., but the high-temperature form is unstable and cannot be studied at room-temperature. A eutectic mixture appears to be formed by CaO and alpha $CaSO_4$ which melts at approximately 1,365 deg. C. The existence of basic sulphates of calcium was not confirmed.

Calcination of Small Limestone.

To meet the demand for calcination of small limestone, the Power-Gas Corporation, Ltd., of Stockton-on-Tees, has acquired rights from the Ellerman Company of Utah, U.S.A., for the manufacture and supply of their patented vertical lime kiln. This type of kiln is suitable for the calcination of small limestone ranging in size from $\frac{1}{4}$ in. to $\frac{5}{8}$ in., and is built in units each having an output of five tons of lime per day of 24 hours.

Industry and the Countryside

The spoliation of the countryside has seemed to be inseparable from the development of some of our mineral resources. In the past it has been all too common for an industry to take minerals from the soil and, when these are exhausted or no longer profitable, to leave a derelict area of slag heaps or other eyesores. In recent years some of this damage has been repaired at public expense, and there is a growing feeling that those who make a profit from the winning of essential minerals should be compelled to leave the site of their operations in at any rate a presentable condition. Messrs. G. & T. Earle, Ltd., have taken a distinct lead in this direction in connection with their Hope cement works, which is situated in one of the most beautiful parts of Derbyshire. They have, indeed, gone further and adopted a scheme, prepared by Mr. G. A. Jellicoe,

Scheme for the Preservation of the Amenities of the Neighbourhood of the Hope Cement Works, Derbyshire.

F.R.I.B.A., the President of the Institute of Landscape Architects, by which, so far as possible, the amenities of the site will be preserved during the whole period of the operation of the factory.

The works is, as is shown in the photograph, situated in a valley. Limestone is obtained from a quarry on the hillside and clay from the pits in the foreground. The photograph is of a model of the works as it will appear when the scheme has been in operation for some years and the trees have grown. The owners of the works have, since the works was built, borne in mind their responsibility for interfering with the landscape as little as possible and a certain amount of tree planting has been carried out and playing fields and other amenities have been provided for the employees. Mr. Jellicoe's scheme provides for the planting of

trees at the entrance to the quarry in order to screen the operations from the opposite side of the valley, the turfing of the bank of spoil in front of the quarry, and the disposal of future spoil inside the quarry. The chief work is, however, to be undertaken at the clay pits, which are to be tidied up and used as lakes for fishing and boating, the banks being planted as shown in the photograph. Schemes such as this must necessarily be carried out over a long period of years, and the annual cost is therefore small compared with the preservation of scenery, the aesthetic value of which cannot be reckoned in terms of money.

The British Standard for Test Sieves.

THE British Standards Institution has issued a revision of B.S. 410 for Test Sieves. Whilst no fundamental changes have been made in the meshes, attention has been paid to the tolerances on the apertures, and modified tolerances on average and maximum apertures have been adopted which are more evenly graded throughout the series. An additional tolerance has been introduced called the "intermediate tolerance," and the maximum percentage of apertures that may exceed this intermediate dimension is specified. For special requirements the new specification includes a second series of sieves with more stringent tolerances designated "Special Test Sieves"; this series will not, however, be manufactured during the war.

The possibility of replacing the medium-mesh wire-cloth sieves by perforated-plate sieves has received attention but it has not been possible to establish the required data and in the present revision wire cloth has been retained for the medium series. The manner of expressing tolerances on the apertures has, however, been brought into line with that now adopted for the fine-mesh sieves. Perforated-plate sieves of smaller apertures than were formerly standardised have been included in the coarse sieve series, and this series has been extended to include a number of larger apertures. As formerly, the revised specification provides for sieves of 8-in., 12-in., and 18-in. diameter, and particulars are given of 3-in. diameter sieves for wet sieving.

An appendix relates to the method of examining the aperture widths and wire diameters of fine and medium-mesh sieves. This indicates the type of projection apparatus required and describes the manner of carrying out the measurements and the number of apertures which have to be measured to determine whether sieves conform to the specification. In another appendix particulars are given for general information of other sieves in common use. Copies of the specification may be obtained from the British Standards Institution, price 2s.

New Method of Removing Clinker Rings.

A NEW method of removing clinker rings from rotary kilns has been patented (U.S. Patent No. 2301855) by Mr. W. R. Cliffe, of Hershey, Pennsylvania. In this method, known as the Cardox-Cliffe process, the rings are blasted by cartridges charged with liquid carbon dioxide (if the temperature is below 88 deg.) which will be instantaneously gasified by a chemical heating mixture ignited by an electric exploder when the blast is made.

On removal of the flame, the ring is clearly seen as an incandescent mass. An approximate position is selected and the plug removed from one of the ports nearest to the chosen point. The drilling guard is screwed into the port coupling, and a light jack hammer is used to drill a hole into the accumulated coating. Fig. 5 shows how these ports were installed. The first drillings are black and fairly cold, but as penetration becomes deeper they are red hot, and if the ring has been missed the entire coating is penetrated suddenly. In this event a length of 1-in. pipe is quickly thrust through the hole, and an observation of its position is taken as it is held extending into the kiln. With this pipe as a guide, the exact position of the ring can usually be determined. The pipe is then withdrawn and the port closed with a piece of brick and the plug then screwed in. A little graphite on the threads, and only turning in the plug two or three threads, make later removal easier. The plug at the newly chosen position is removed and the drilling operaton repeated.

In a recent test the refractory lining at this position was 9 in. thick, the kiln shell was ¾ in., and the coupling extended 2½ in. from the kiln shell. There was thus 12¼ in. from the inside surface of the refractory lining to the top of the connector coupling. The gas-escape ports of the cartridge should be 1 in. to 2 in. beyond the inside surface of the refractory lining, and these ports are about 3 in. from the end of the cartridge. Thus about 4½ in. had to be added, making a total of 16¾ in. from the outer edge of the coupling to the base of the drilled hole. By allowing for the space of the drilling guard the drill can be marked, and when these marks register the hole has been drilled to sufficient depth. As the ring was of sufficient width to permit of two simultaneous shots being made, the adjacent plug was removed so that another hole could be drilled. While these holes were being drilled in the ring, the clamps were attached to the cartridges. The position of the clamps was determined by the length of the cartridge guide plus the previously determined distance from the top of the coupling to the hole depth (see Figs. 4, 6 and 7). Short lengths (about 3 ft.) of electric exploder wire were attached to the terminals of the cartridges and the exploder circuit tested with a small portable galvanometer ; this reveals the condition of the electrical exploder circuit.

When both holes were drilled into the ring to the proper depth the cartridge guides were screwed into position. The cartridges, with the clamps in position, were inserted and the yokes pushed into place. Then the electrical connections were made so as to fire the two shells simultaneously. The kiln was then turned so that the cartridges were on the underside, and the charges exploded. The kiln

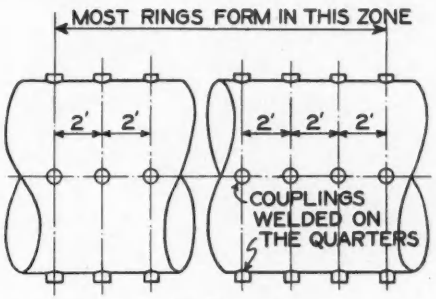


Fig. 1.—Position of Ports.

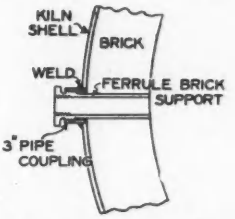


Fig. 2.—Ferrule Replaceable from Outside.

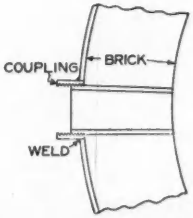


Fig. 3.—Ferrule Replaceable from Inside.

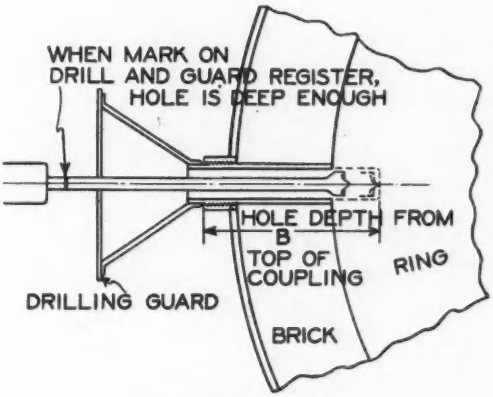


Fig. 5.—Drilling Guard.

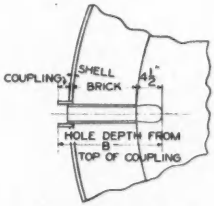


Fig. 4.—Details of Drilled Hole.

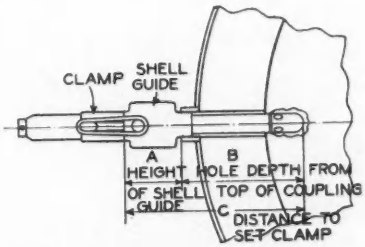


Fig. 6.—Preparation of Charge.

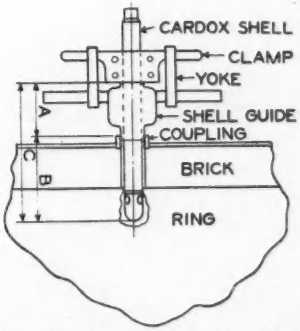


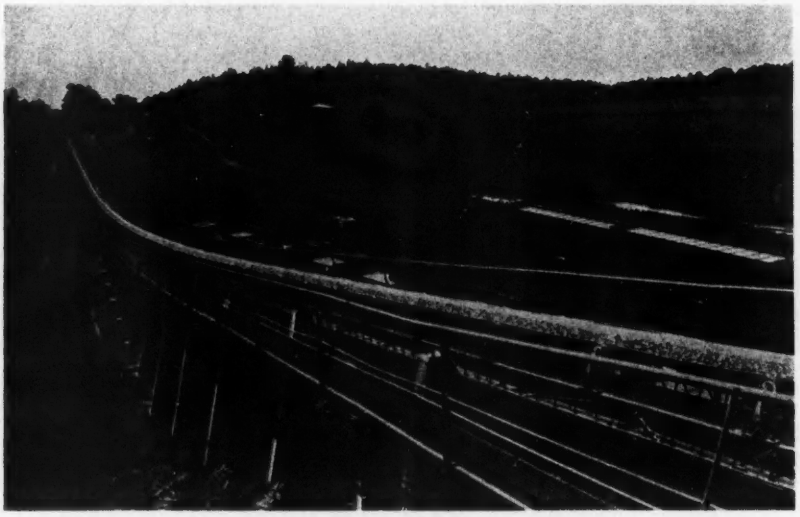
Fig. 7.—Charge Ready for Blasting.

was then turned so that the exploded cartridges were at the top, the wires removed, the yokes pulled off, and the spent cartridges extracted. Pieces of brick were driven into the ports and the plugs screwed into place. As the kiln turned, large chunks were seen tumbling about inside. A big gap was seen in the ring and pieces continued to fall out as the fire was put on and the kiln continued to turn. It is claimed that the result of this test was entirely satisfactory. The whole of the process occupied forty-five minutes, but it is expected that with more experience it will be possible to remove a clinker ring in fifteen minutes or so.

A Long Belt Conveyor for Raw Materials.

A BELT conveying system for the transport of cement raw materials over a distance of 6,500 ft. between the quarry and the factory has been installed at a works in Alabama of the National Cement Co. Five days' operation per week supplies sufficient material for seven days' requirements at the cement factory, leaving two days a week when the conveyor is not working and maintenance can be carried out. Very little excavating was done, and the belts follow the contour of gently rolling hills. Also, the seven units comprising the system are not in a straight line but form an arc of large radius.

The belts are 24 in. 6-ply. Each unit is about the same length and is driven by a 25 h.p. motor through a gear reduction unit and enclosed, oil-tight, roller-chain drives. The system has a capacity of 225 tons per hour. All electric motors are connected to a switchboard in such a manner that failure of any



Section of Belt Conveyor 1¼ miles long.

unit or stoppage of flow of material causes the entire system to stop. The rolls are spaced on 5 ft. centres for the carrier rolls and on 10 ft. centres for the return rolls. A few guide rolls are installed to overcome minor belt misalignments due to wind. One operator looks after the greasing and maintenance of the entire system, and makes three to four trips per day over the system.

Both limestone and clay are handled by the conveyor system, as both materials are available from the same pit ; one face supplies the stone and the other supplies two grades of shale, one a high-alumina shale and the other a high-silica material so that proper mixes can be obtained from the one pit. After eighteen months' operation no repairs have been needed except of a very minor nature.

Structural members carrying the troughing and return rails are made up in 16 ft. sections of $\frac{3}{4}$ in. round reinforcement bars. Longitudinally there are four

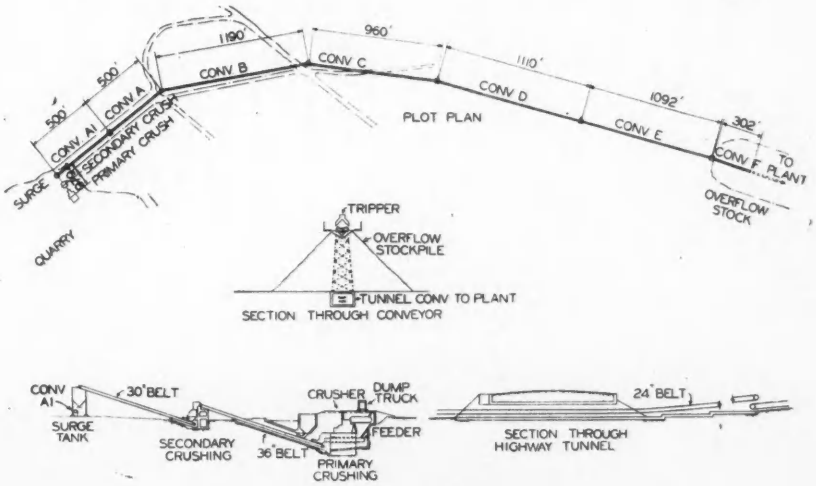


Fig. 2.—General Arrangement.

bars, two at the top and two about 7 in. below the upper bars. The diagonal trusses comprise $\frac{3}{8}$ in. diameter bars electrically welded. These are cross-braced with electrically welded $\frac{3}{4}$ in. bars. The 16 ft. sections are mounted on concrete piers.

The belts are protected from the weather by a frame made up of 4 in. by 2 in. and 4 in. by 1 in. timbers covered with galvanised iron. Cattle are kept away from the belts by a barbed wire fence on concrete posts. At one point the conveyor passes under a road through a reinforced concrete tunnel. The motors and gear-reduction units are housed in corrugated-iron buildings.

The tail pulley on all the units is of the floating type. The 24 in. diameter pulley is mounted on four small flanged wheels riding on a steel track. By means of a steel cable, sheave and counterweight, proper tension is maintained on the

belt at all times. The counterweights are concrete blocks assembled in a steel framework.

Crushed limestone (or clay) on arrival near its destination passes up-grade. Here the conveyor is carried on concrete pillars up to about 20 ft. high. The crushed material at this point is unloaded by a tripper to storage.

In the quarry the limestone is blasted from the face and secondary drilling is done with jack-hammers. From a jaw crusher the stone falls on to a 36 in. belt conveyor that delivers to a second pan feeder serving a hammer mill. A 30 in. inclined belt delivers to a small cylindrical steel tank, from which the stone (or clay) is delivered to the belt conveyor. The feed to the belt is controlled by a feeder to which is attached a counter. This bin is provided with an electric vibrator to jar down any material that tends to hang up. At the end of the belt is a device that actuates a signal at the hammer mill so the operator is warned of any trouble along the belt line. Some details of the conveyor are given in Fig. 2.

General Refractories, Ltd.

MR. T. WATSON has been appointed a director of General Refractories, Ltd., Sheffield. Mr. Watson joined the Company in 1929, and since 1931 has held the position of commercial manager.

★ **These are the reasons why :—**

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Fuel Consumption in Rotary Lime Kilns.

IN the course of some notes on fuel economy in the rotary lime kiln, written by Mr. Ralph Gibbs and published in " Rock Products," it is pointed out that with large kilns coming into favour thermal efficiency becomes an important factor in choosing the proper size mill to pulverise the coal. A kiln capable of producing 150 tons of lime per day with a coal ratio of 2·22 to 1 must, with a direct firing unit pulveriser, have equipment and power to pulverise about 5,600 lb. of coal per hour. With a fuel ratio of 4 to 1 the fuel requirement is only about 3,200 lb. per hour. Thus, beside the saving in operating expense, there would be considerable saving in first cost, since a smaller direct firing unit could be used. Shut-downs, especially of short duration, are costly. The refractory lining in particular suffers. Fuel costs rise because during the heating up period more than normal quantities of fuel are used and production is negligible. Consequently attempts are usually made to keep the kiln operating at reduced capacity. Regardless of the method of attaining this result, the thermal efficiency will be reduced by reason of the fact that the normal heat losses remain fairly constant, especially that through the kiln shell, and thus become larger in proportion to the total heat involved in the process.

Coal cannot be used as received. In some instances it is dried, pulverised, and the finished product stored in bins prior to use. In most cases, however, it is sized, stored in bins, and pulverised just prior to delivery into the kiln. The latter system is coming into favour, and it is justified by improved safety conditions and by greater economy of labour. Furthermore, the unit system of direct firing, with most coal pulverising units, provides a fairly constant flow of fuel as well as means of immediately changing the flow-rate.

In order that the pulverising unit be assisted in its task of delivering a constant supply of fuel to the kiln, it is advisable to provide it with properly sized coal. To have very coarse coal fed to the pulveriser one time and very fine coal the next results in irregular delivery of pulverised coal to the kiln. By making the supply of coal to the pulveriser more uniform in size, the delivery of the finished material to the kiln will be more uniform in quantity and quality. In selecting such a unit there are many factors to be considered. First is the determination of the quantity of fuel required per unit of time. Secondly, the grindability of the coal to be used should be known, since this factor affects the capacity of the pulverising unit. Thirdly, the power required to drive the mill and accessories should not be excessive. Fourthly, parts of the mill subject to wear and replacement should be studied with regard to maintenance.

The properly proportioned ball mill carries a reserve supply of fuel while it is operating, thus permitting ample time for grinding as well as allowing ample time for the hot air to dry the coal if it is wet. Tramp iron is not detrimental and no special provisions are necessary for its entrapment and removal. A fixed level of coal can be constantly maintained in the mill, thus assuring maximum coal

pulverising effectiveness and minimum wear on the liners. Maintenance costs are thus at a minimum. The power required to drive a well-designed ball mill unit and its accessories is low. With automatic control of the coal level in the mill, the control of fuel delivered to the kiln is extremely sensitive, and the balancing of the combustion process can be easily performed. Primary air can be closely regulated, and thus the characteristics of the flame of the burning fuel can be modified to a certain extent.

The rotary kiln is operating at its maximum efficiency when it is producing an optimum quantity of suitable finished material with the least amount of fuel possible. If the fuel is being burned under conditions of balanced combustion, there is nothing further that can be done to improve this part of the process. Attempts to produce excessively large quantities of the product will result in poor quality, either because the material is not subjected to a sufficiently high temperature, or not allowed sufficient time for the reactions to be completed. On the other hand, when too small quantities are produced there are difficulties because the material is over-processed. Consequently, between these limits of under-processed and over-processed material there is an optimum production rate at which the kiln is working most efficiently. The task, therefore, is to burn the fuel under conditions of balanced combustion and maintain as closely as possible the flow of material through the kiln at the optimum rate. The most convenient way of performing this is by regulating the rotation of the kiln.

An empirical equation developed by the writer to predict the approximate economical production capacity of rotary kilns is

$$T = \frac{kD^2L}{100}$$

in which T = tons produced per day, D = diameter of kiln shell in ft., L = length of kiln in ft., and k is a constant, its numerical value depending upon the kind of material being produced. No claim for great accuracy is made for this simple relation, especially when L is greater than 300 ft. Nevertheless, it predicts within practical limits the optimum rate of kiln production.

Another feature of the rotary kiln is the depth of the load of the kiln. Ordinarily there is a retaining dam at the feed end. Its major purpose is to retain a fixed depth of load in the kiln. In addition to this, however, it affords a restriction in the path of the gases leaving the kiln, and thus affects the fuel-burning capacity of the system. As this dam is made higher the load becomes greater, but the opening becomes smaller and the ability to burn fuel under conditions of balanced combustion and under identical conditions of draught is decreased. In order to determine the optimum height of this dam, we have simply to plot the two curves shown in *Fig.* 1. *Fig.* 2 illustrates the relation of the dam and the free opening or free area.

The curves are based upon two assumptions: first, that under conditions of balanced combustion and identical draught, the fuel burned is proportional to the free area at the feed end of the kiln; secondly, that the fuel requirement of the load is directly proportional to the area of the segment of height h. Curve A

is the result of plotting the value of the free area against the height of the segment. This relates the fuel-burning capacity of the arrangement to the height of the dam. Curve B is developed from the area of the segment of height h and the free area proportional to it. Since the area of the segment represents the quantity of material per unit length of the kiln it therefore represents also the heat required. Thus curve A relates the heat that can be produced or developed, and curve

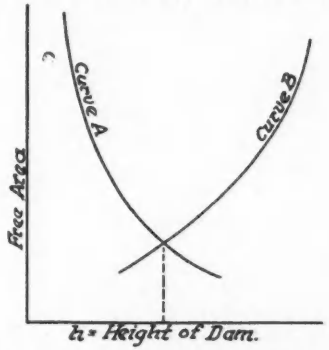

Fig. 1.—Optimum Height of Material Dam at Feed End of Kiln.

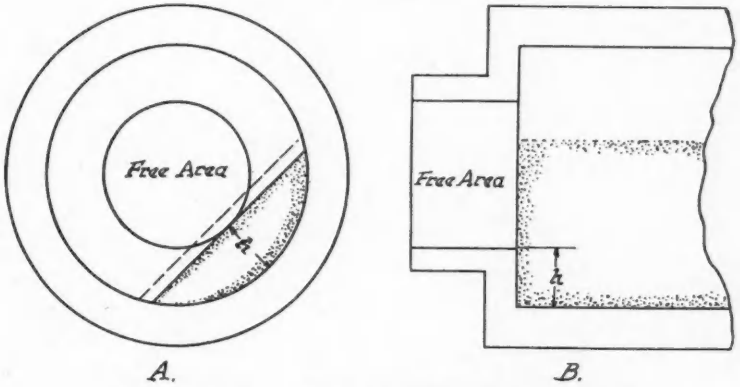

Fig. 2.—Relation of Material Dam and Free Opening.

B the heat that is required, to the common factor of the load depth. The point at which these two curves intersect shows the optimum height of the dam.

Heat is transferred to the load by radiation, convection and conduction. Toward the feed end of the kiln the heat is largely transferred by convection and conduction. The hot kiln gases, of low luminosity, heat the kiln wall and load largely by convection, as they travel toward the gas outlet of the kiln. Since the kiln wall is exposed to the hot gases for a greater period of time than the average load particle, the kiln wall is at a higher temperature than the load, and as the

particles roll upon themselves and finally rest upon the hotter kiln lining during the cycles of travel they become heated by conduction.

In the vicinity of that portion of the kiln wherein the actual combustion of the fuel is taking place, enormous quantities of energy in the form of heat are being released through the medium of flame, the nature of which is yet only superficially understood. This released energy is transmitted to the walls of the kiln and the load surface at a rate proportional to the fourth power of the absolute temperature and received with an intensity inversely proportional to the square of the distance between the flame and the receiving surfaces. A long, rolling "soft" flame is totally different from a short, snappy, "hard" flame. In the former, the result is a lengthening of the zone in which most of the heat is being transmitted by radiation, and it is at a lower temperature than the equivalent zone wherein a "hard" flame is maintained. In the case of a hard flame, the high temperature zone is hotter and of shorter length. The explanation for this is simple. Let us assume that we are burning bituminous coal in a rotary kiln at a rate of 50 lb. per minute and conditions are such that there are 15 ft. from the point of ignition to the tip of the flame. With a coal of heating value 13,500 B.T.U. per lb. there is a release of 675,000 B.T.U. per minute, or 45,000 B.T.U. per minute per foot of flame. By lengthening the flame to 25 ft. from the point of ignition to the tip without changing the rate of firing fuel, we have only 27,000 B.T.U. per minute per foot of flame. Thus the heat of combustion given off as radiated heat, being distributed over a larger surface, results in that surface receiving the energy reaching equilibrium at a lower temperature level.

The Care of Sacks.

A further request for the exercise of care in the handling of sacks has been issued by the Ministry of Supply. The Ministry states that the utmost economy in the use of sacks is absolutely necessary, and all users are asked to ensure that each sack is used only for essential purposes, and that it is used as many times as possible. The following rules are given for the care of sacks: (1) Handle sacks and bags with care so that they can be used over and over again; (2) Keep sacks dry. If they are wet, dry them as quickly as possible to prevent rotting and spontaneous combustion; (3) Do not stack sacks directly on damp surfaces; (4) Never drag full sacks over rough floors or over the ground; (5) Do not allow full sacks to be tumbled from wagons or lofts, as this may cause them to burst; (6) Avoid overfilling, which causes strain in handling and stacking; (7) Keep them clean; (8) Do not store them where they can be contaminated; (9) Do not allow them to be damaged by vermin; (10) When opening sacks the string only should be cut; (11) Never allow empty sacks to accumulate. Return "returnable" bags as soon as possible after emptying. Non-returnable bags must be disposed of to recognised collectors; (12) If a sack is damaged have it repaired or dispose of it to an authorised dealer; (13) If a sack or bag is beyond repair send it for salvage; (14) Make one or more persons responsible for the care of sacks and bags; (15) Return idle sacks and any that are in use for unnecessary purposes.

National Bureau of Standards
MAR 2 1943

CEMENT AND LIME MANUFACTURE

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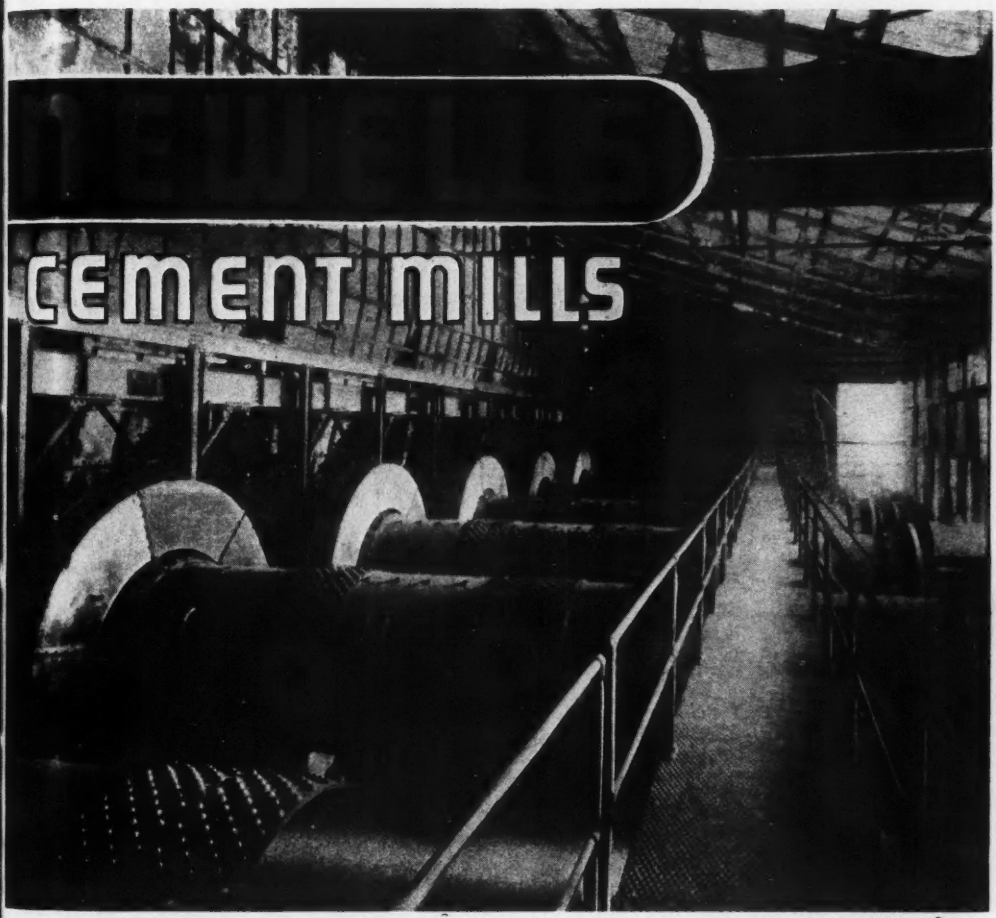

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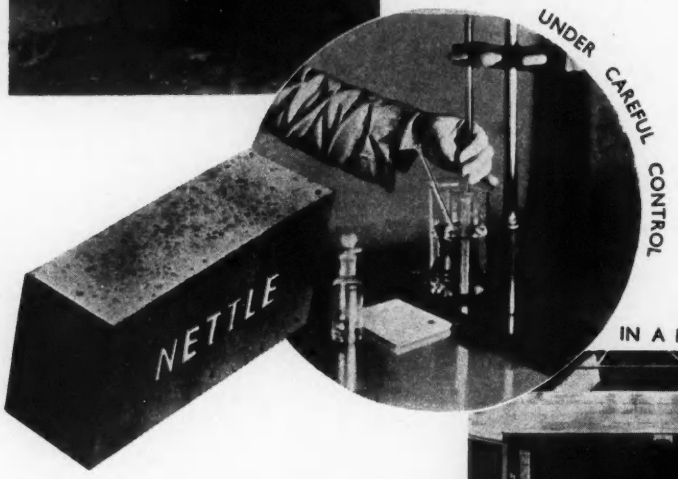

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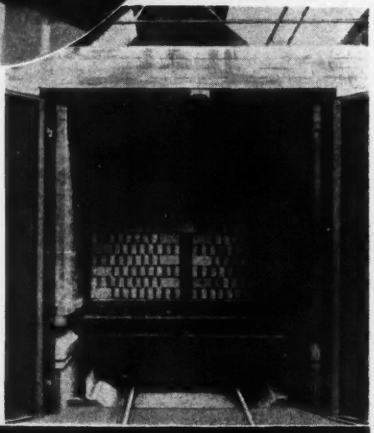

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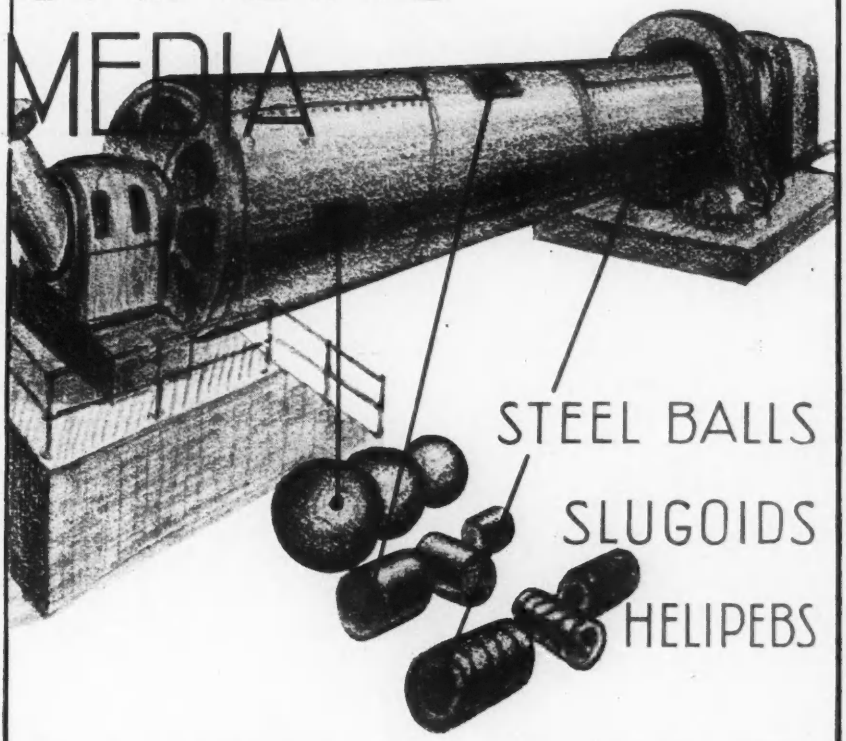

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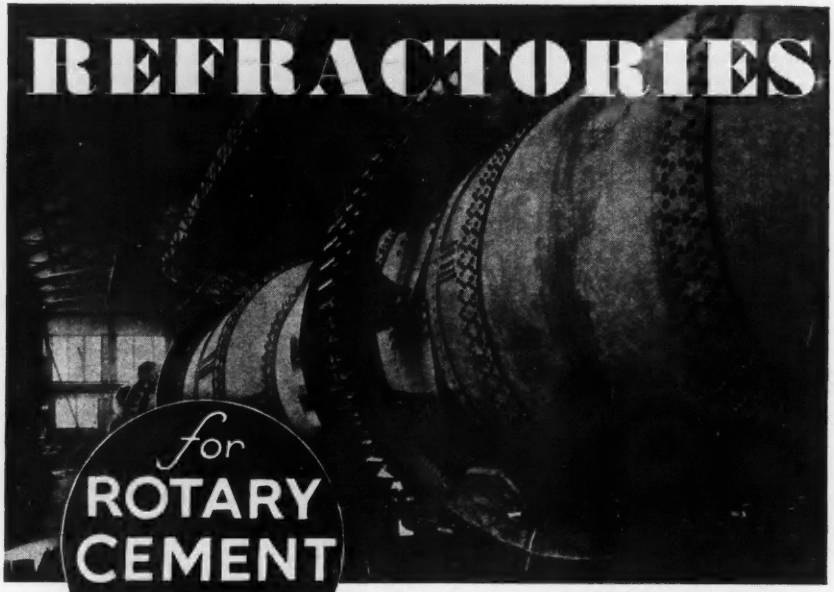

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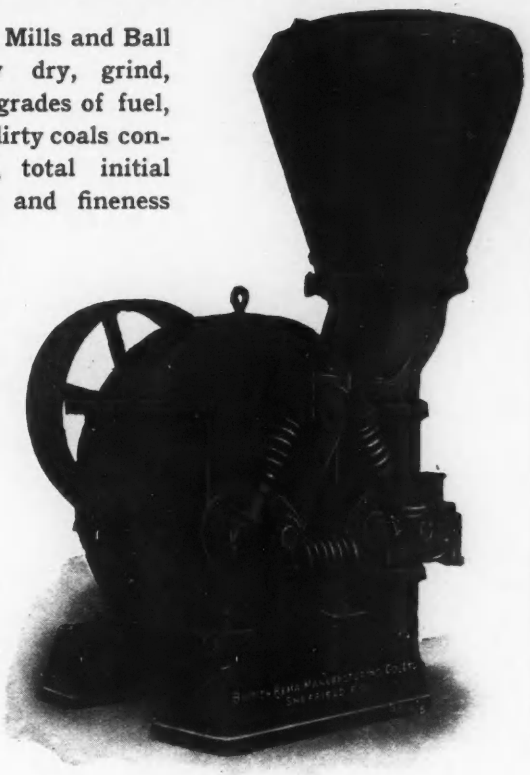

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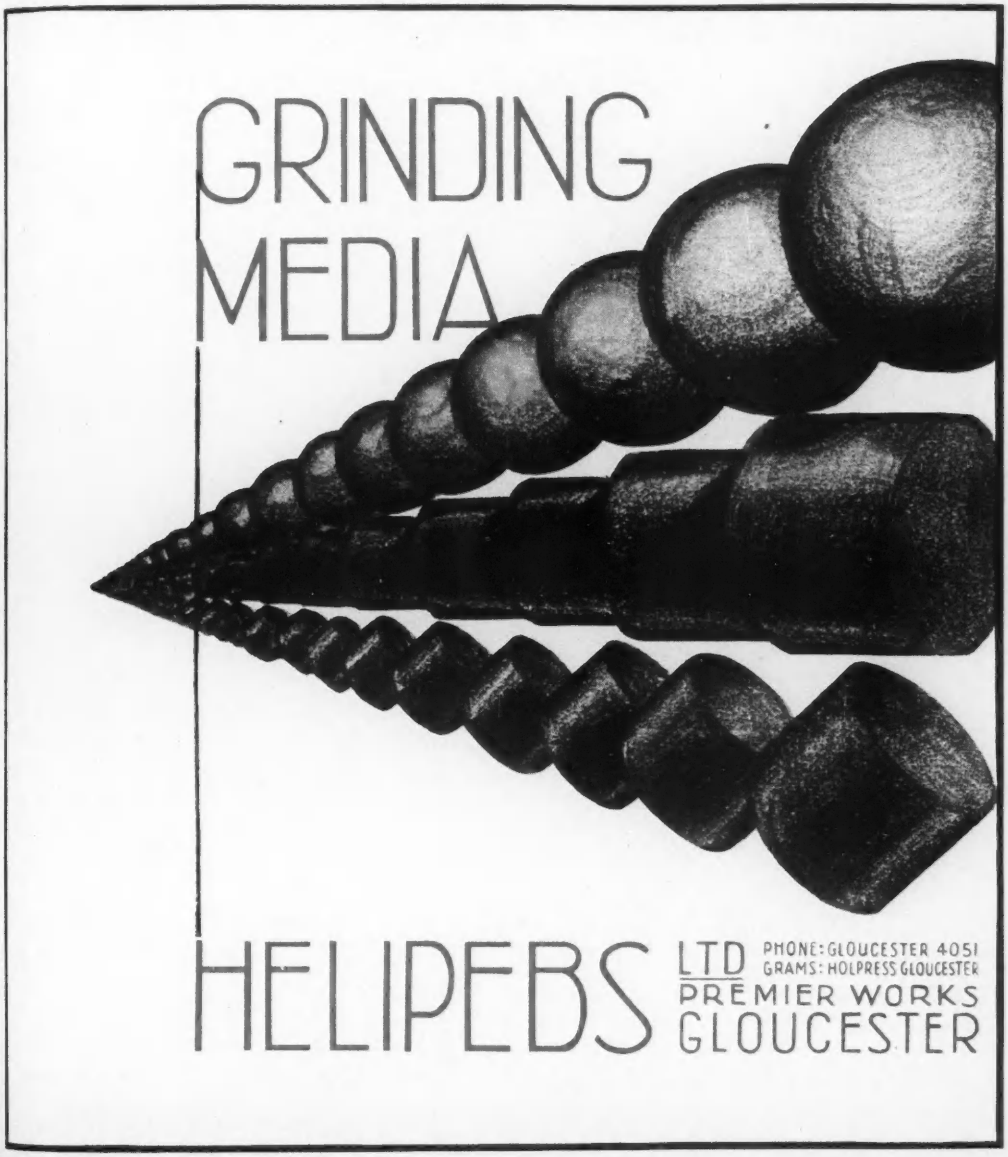

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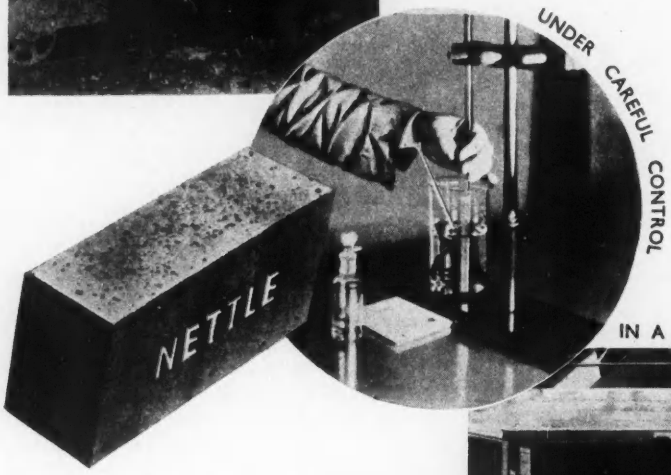

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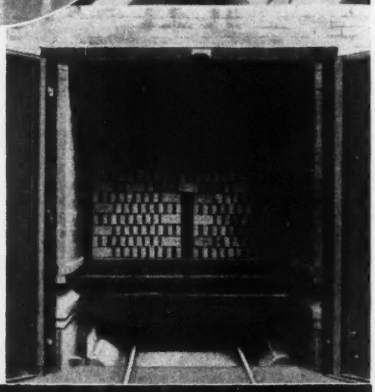

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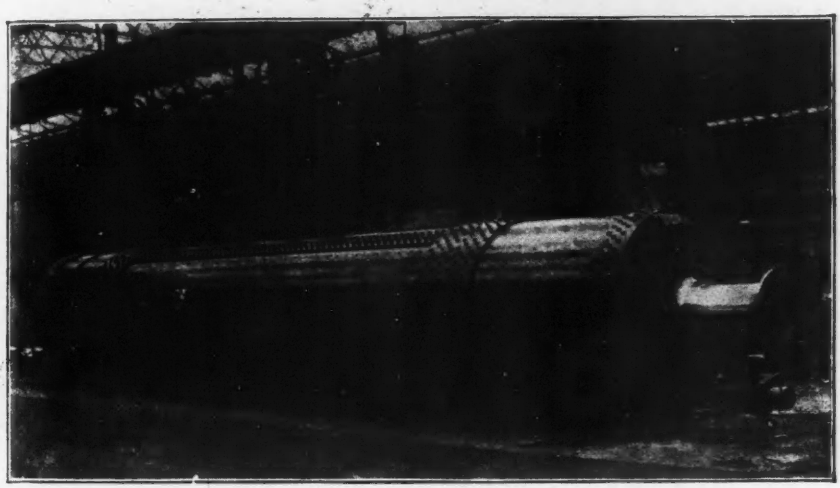

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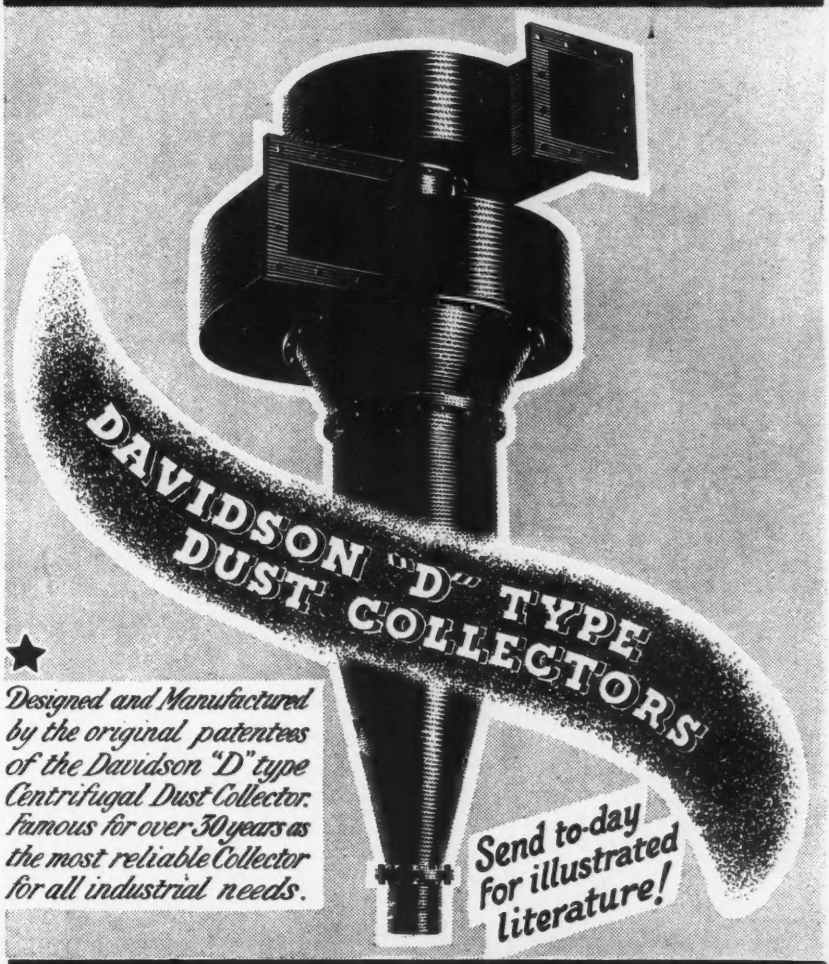

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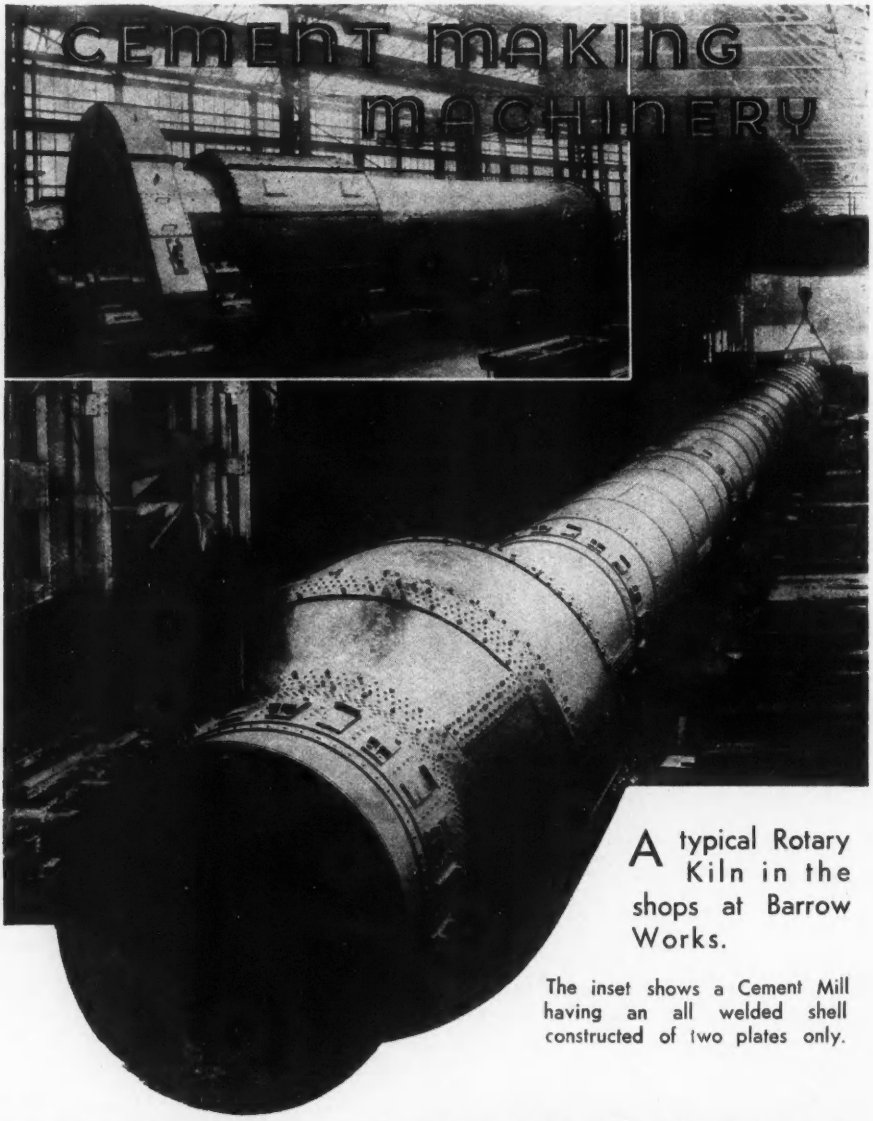

A typical Rotary Kiln in the shops at Barrow Works.

The inset shows a Cement Mill having an all welded shell constructed of two plates only.

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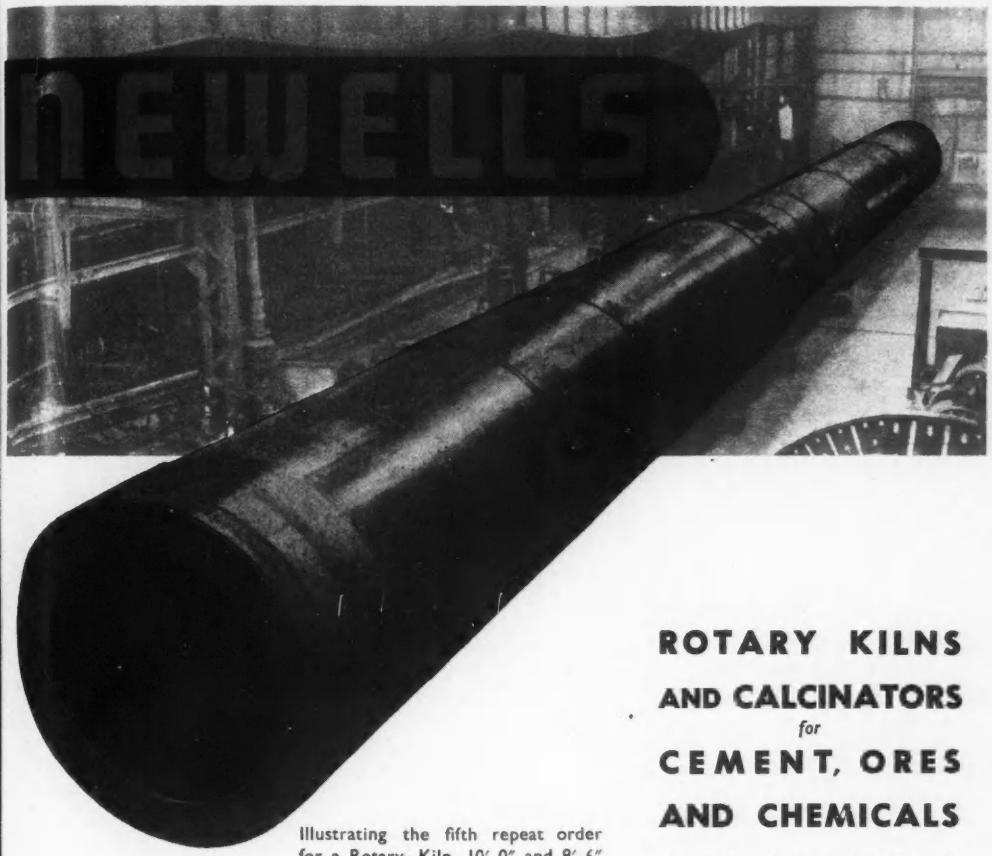

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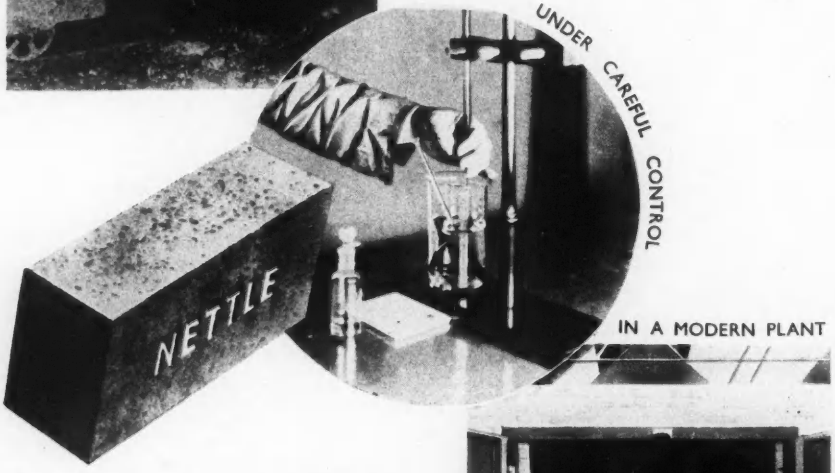

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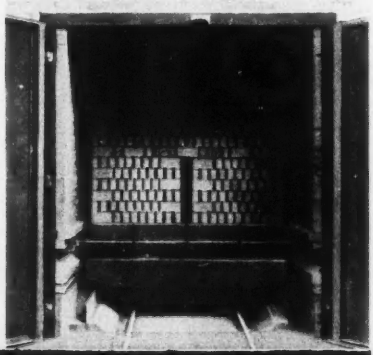

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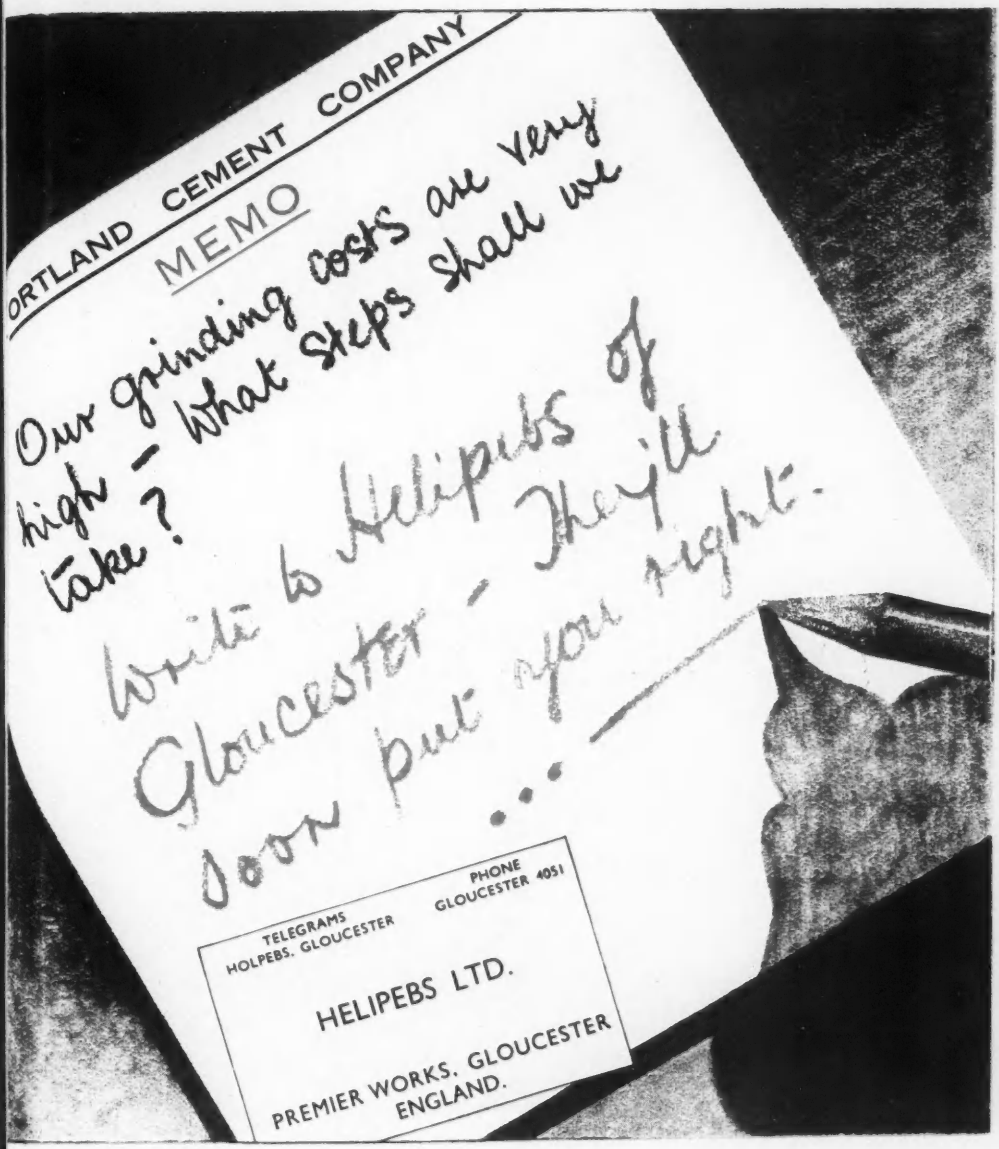
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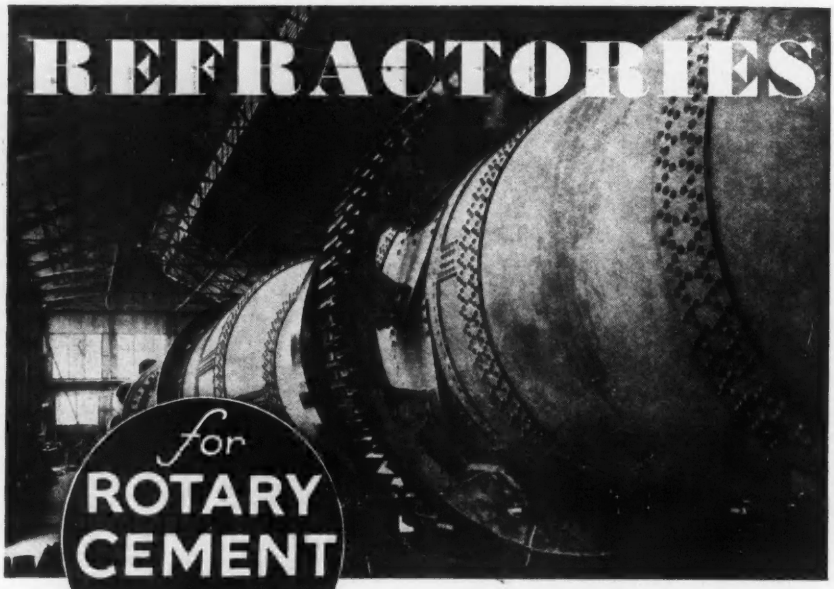

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For the Feeding End—ADAMANTINE.
"Adamantine" brand is recommended for this section. This material is hard, tough and unaffected by lime, alkalis or moisture, and resistant to any changes of temperature likely to be encountered. These bricks are renowned for the length of service given.

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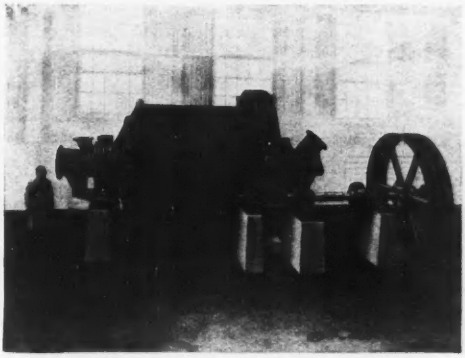

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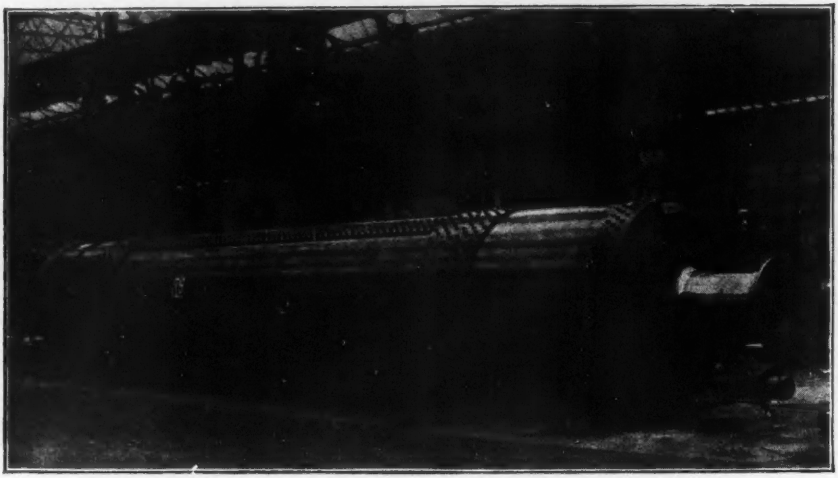

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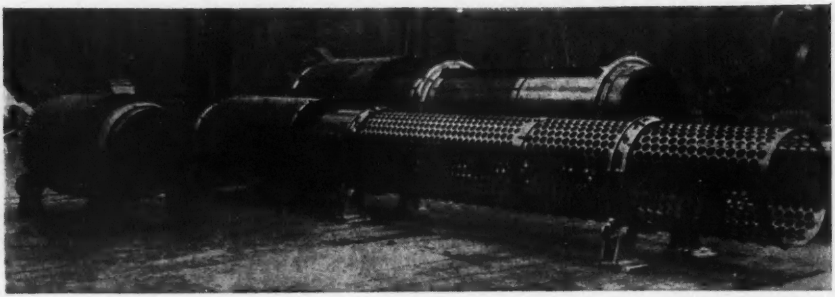

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CEMENT AND LIME MANUFACTURE

National Bureau of Standards
MAY 17 1943

VOL. XVI. No. 4 APRIL 1943 PRICE 1/- MONTHLY

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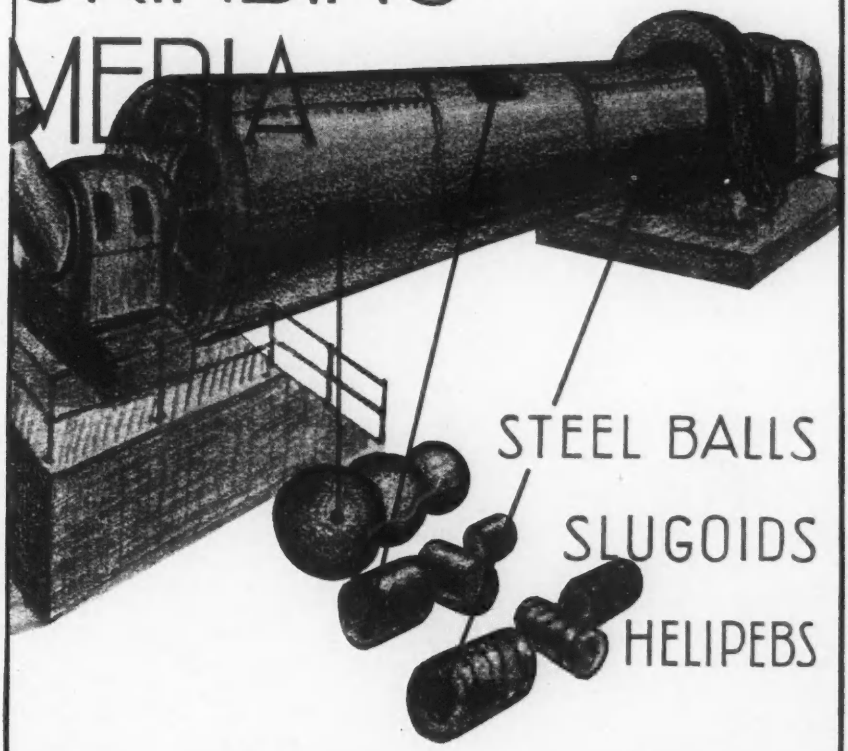

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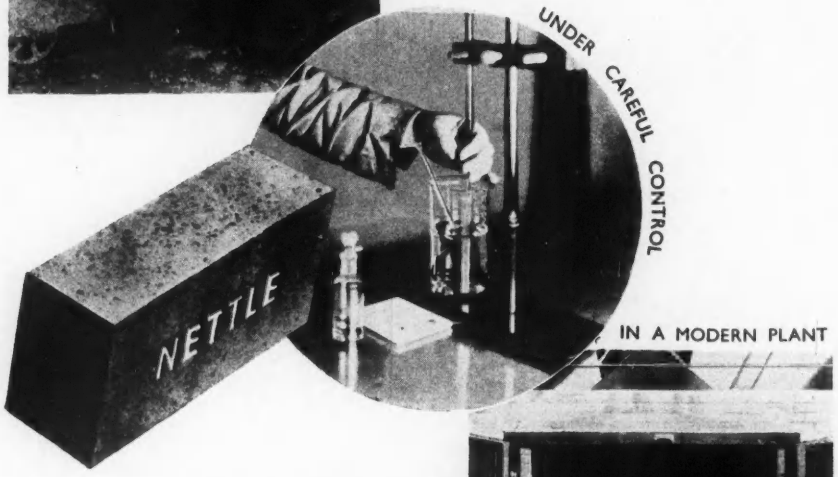

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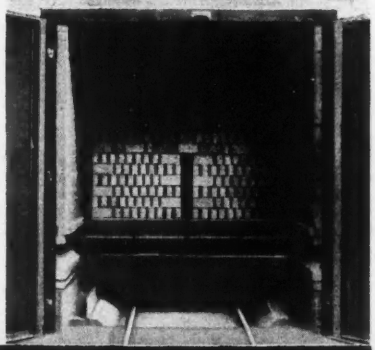

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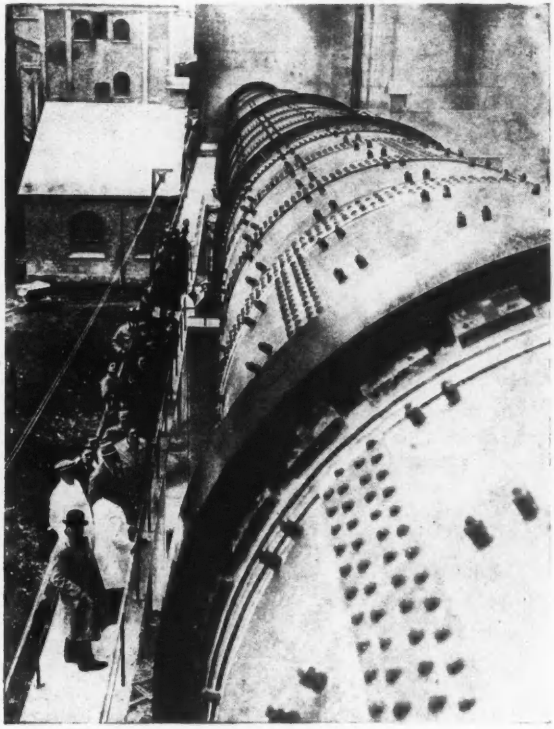

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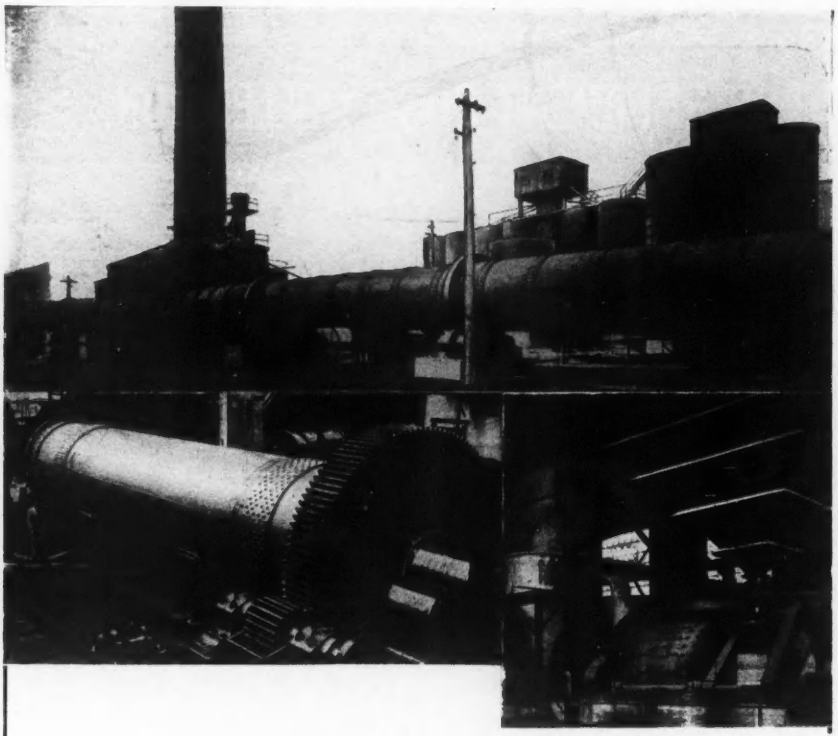

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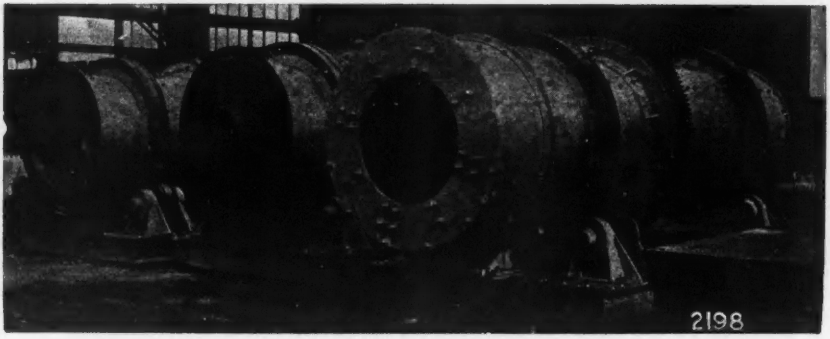

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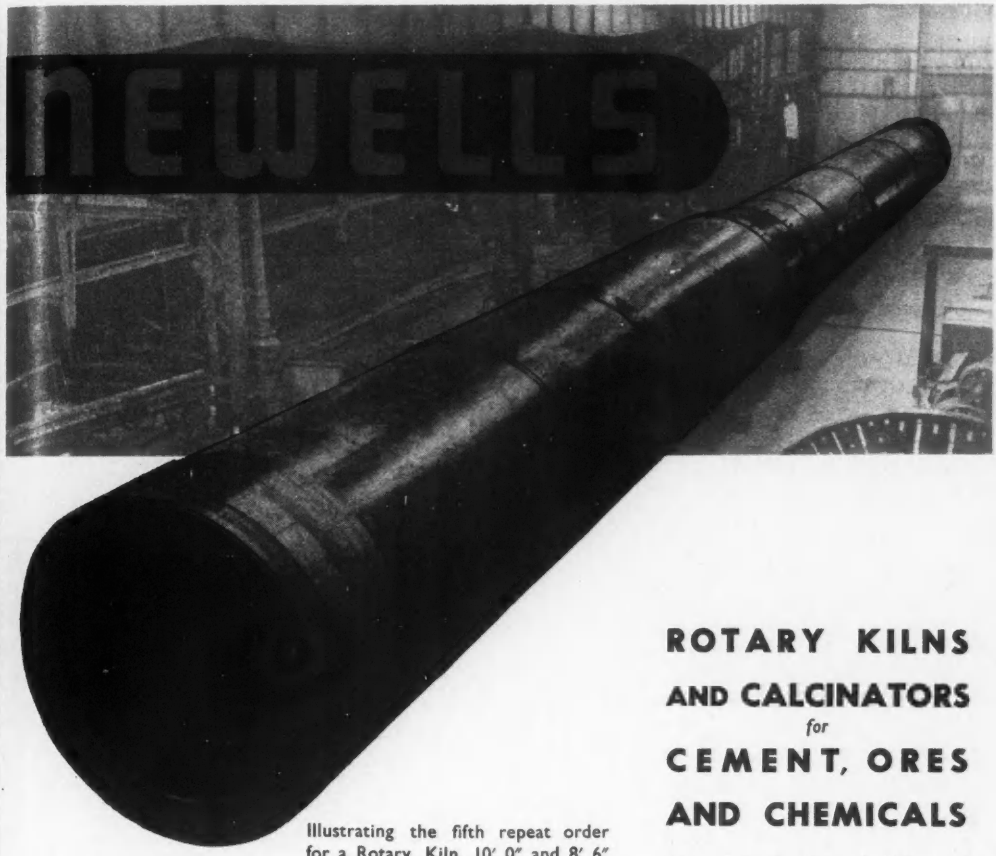
JUN 14 1943

VOL. XVI. No. 5 MAY 1943 PRICE 1/- MONTHLY



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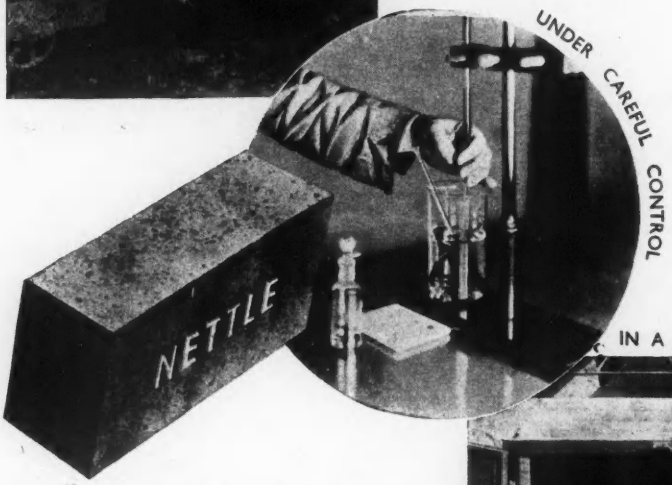

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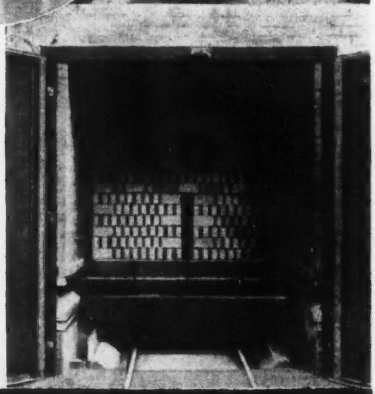

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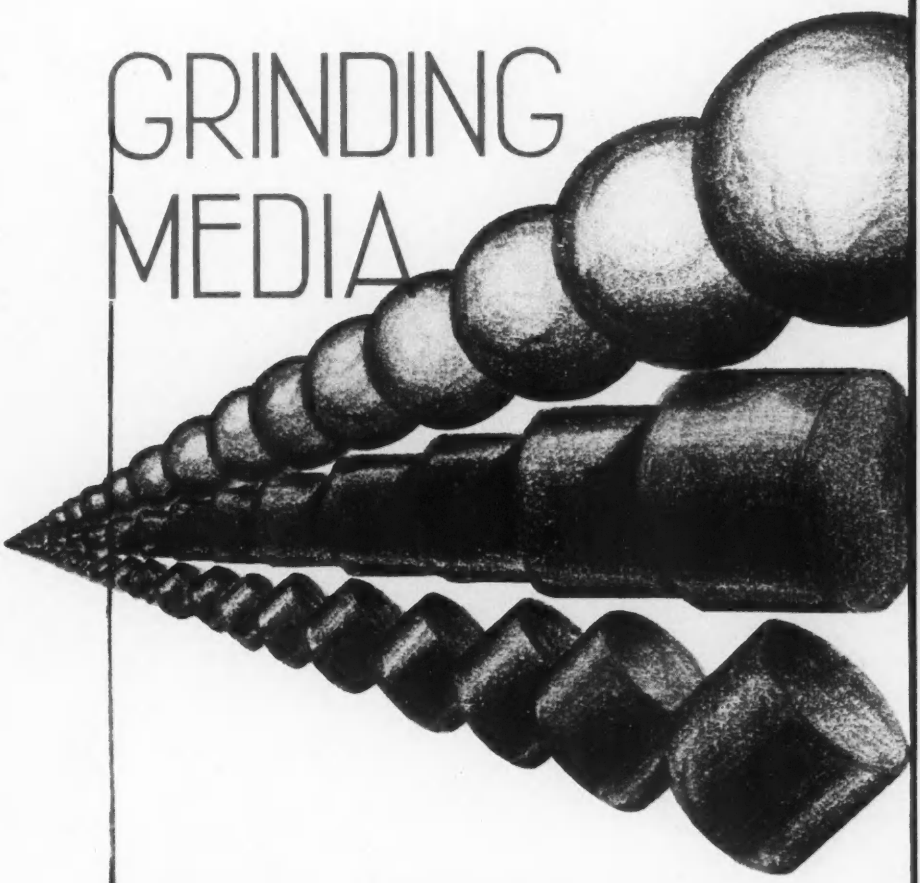

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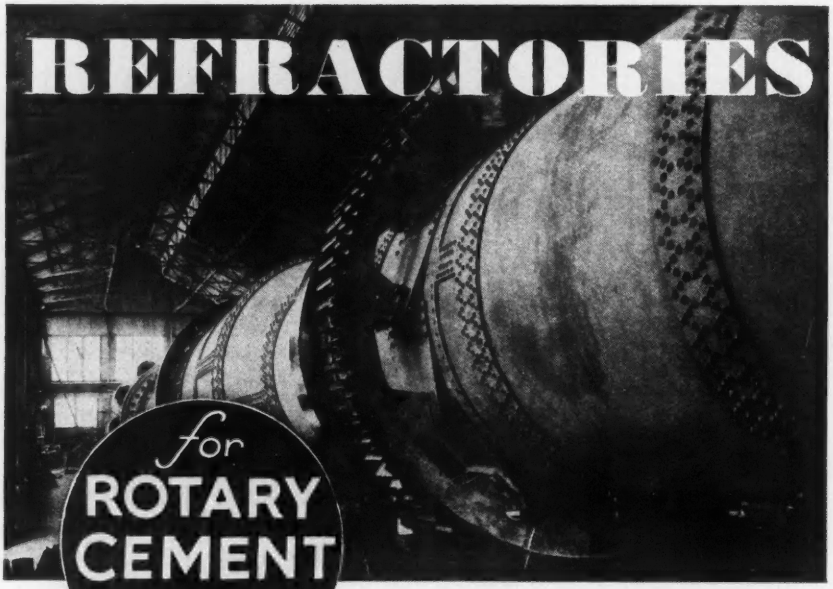

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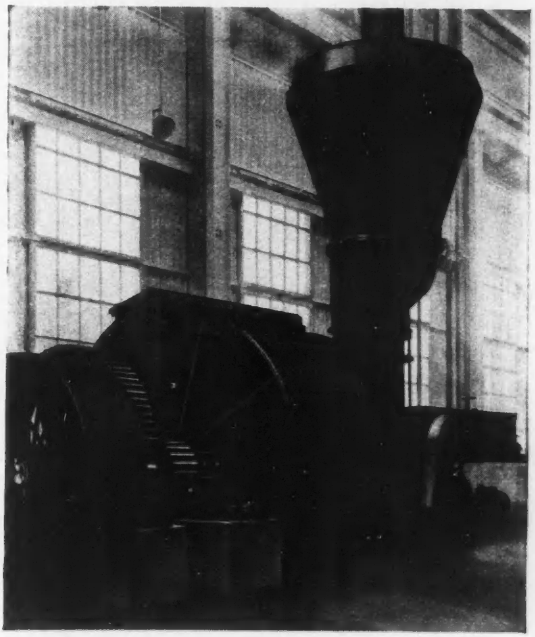

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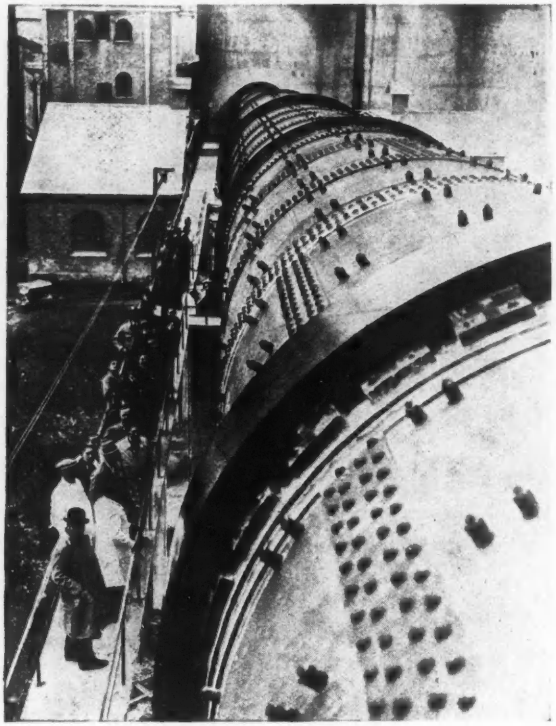

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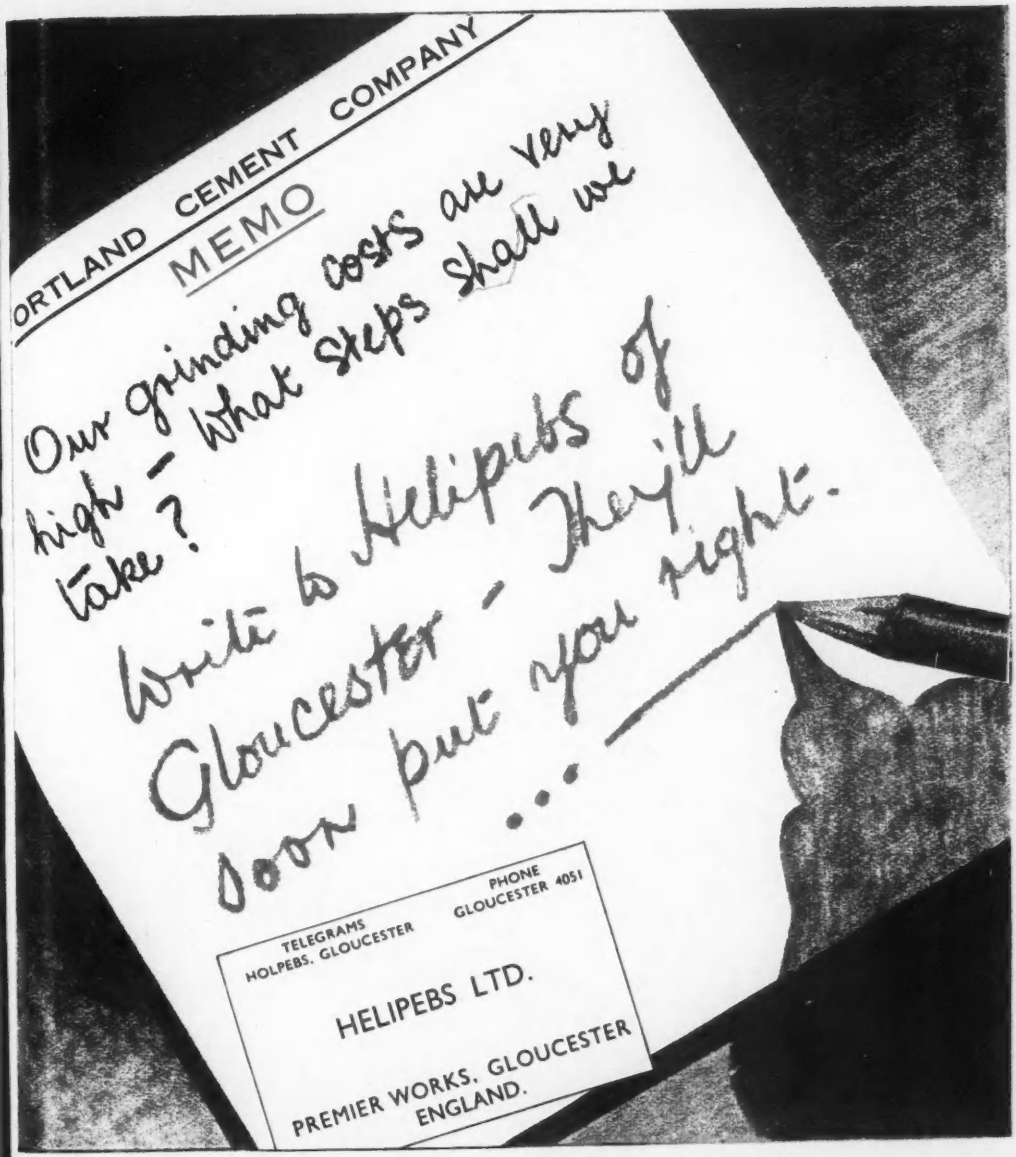
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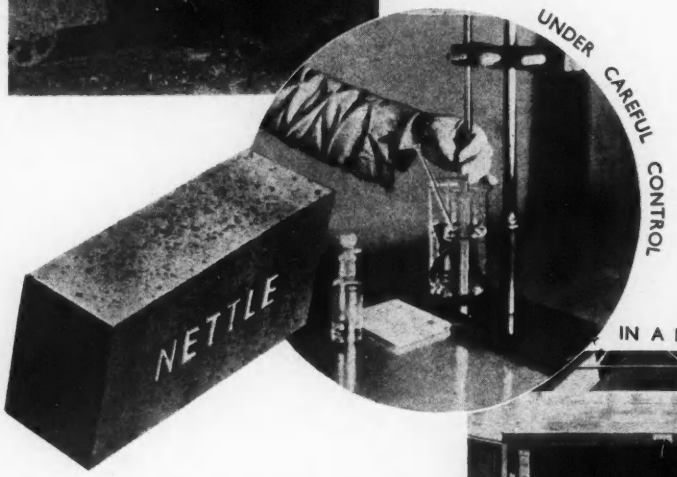

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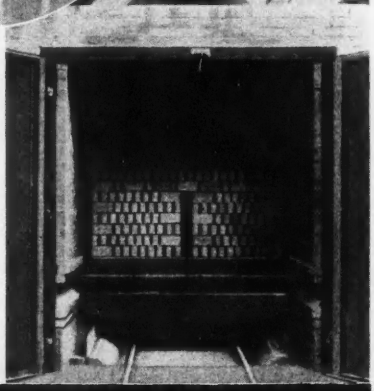

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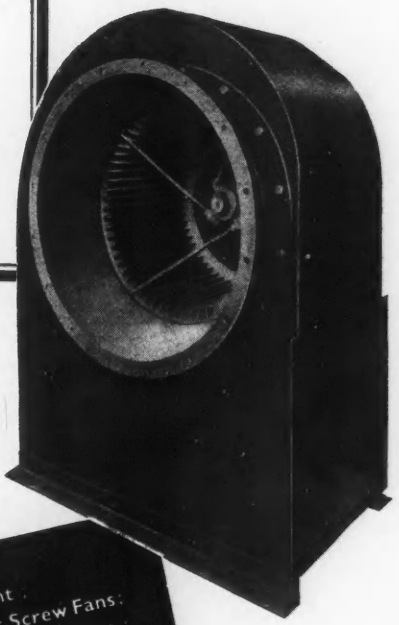

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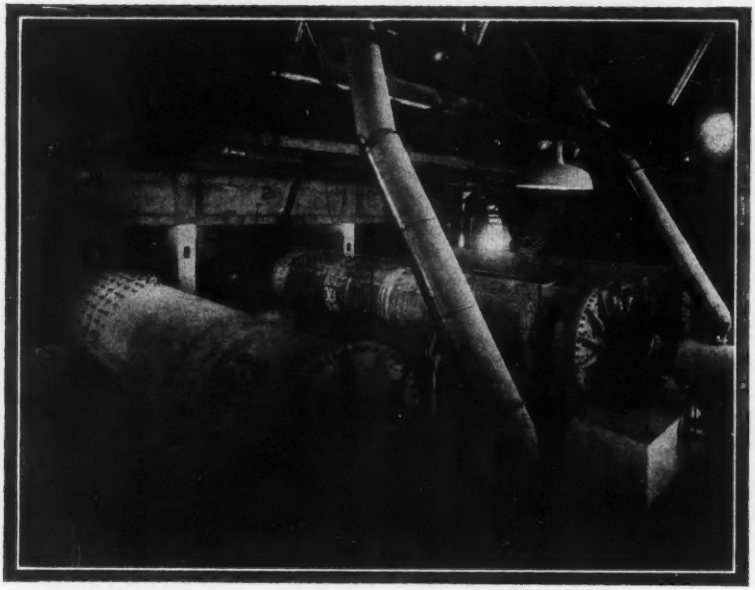

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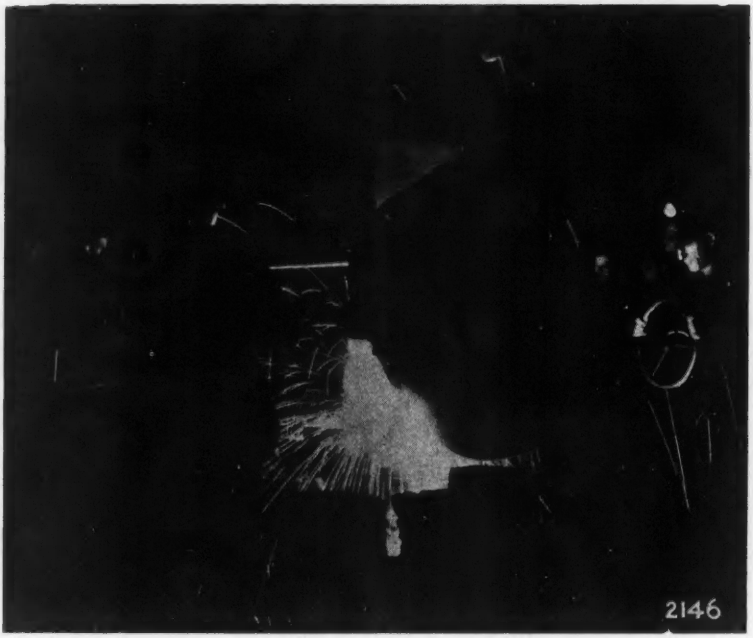

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CEMENT AND LIME MANUFACTURE

National Bureau of Standards
AUG 10 1943

VOL. XVI. No. 7 JULY 1943 PRICE 1/- MONTHLY

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ROTARY KILNS
CALCINERS · COOLERS
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supplied
IN THE LAST THREE YEARS

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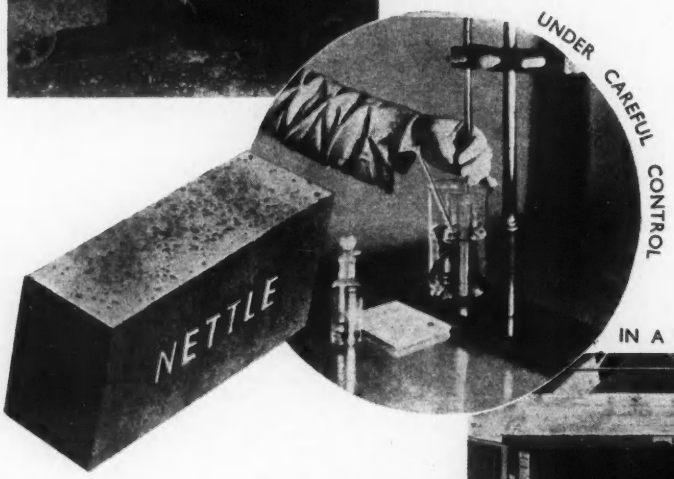

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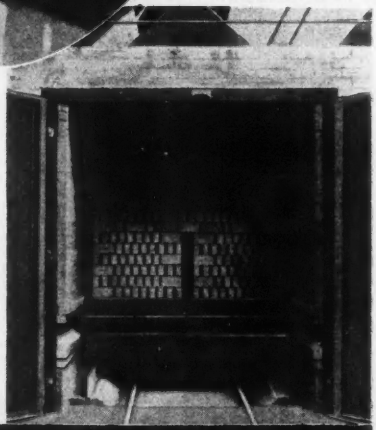

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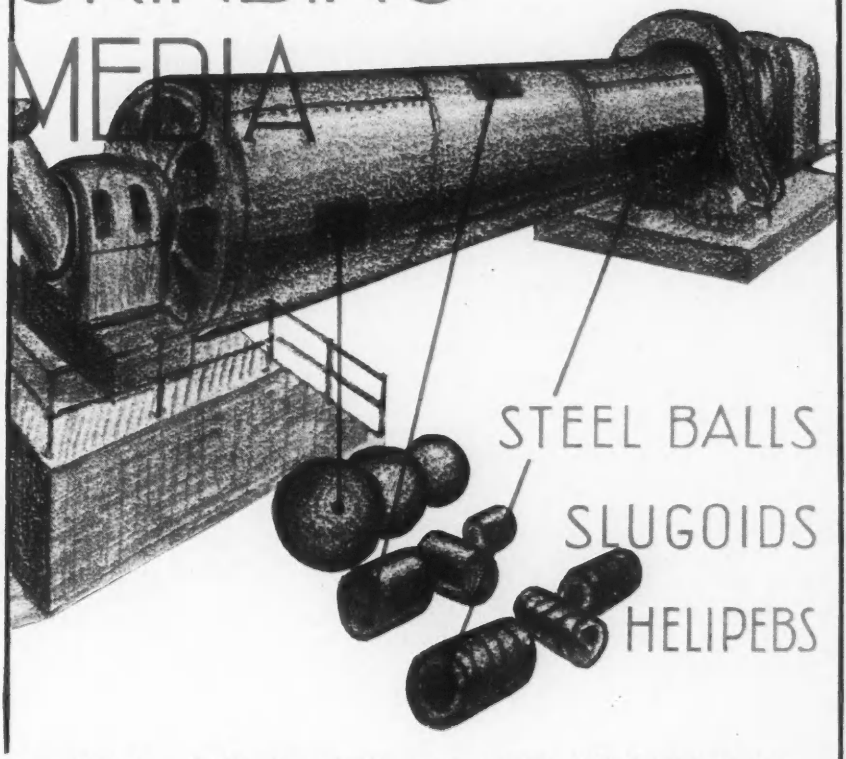

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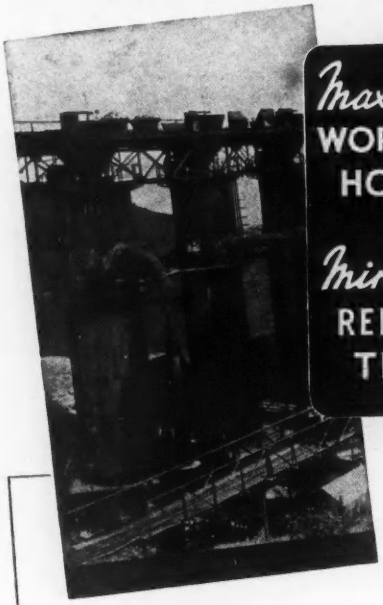

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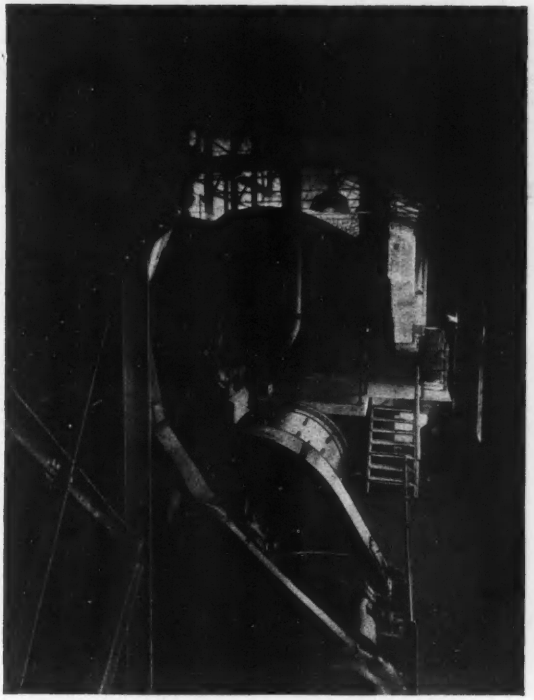

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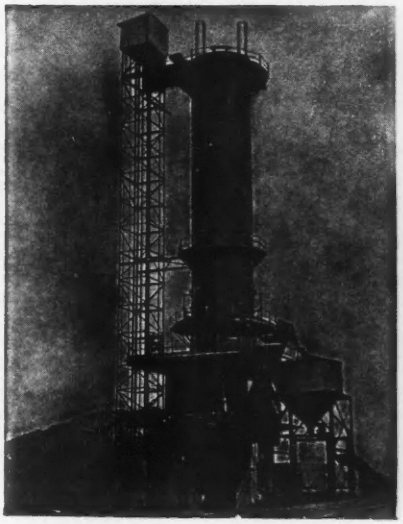

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of capacities ranging from
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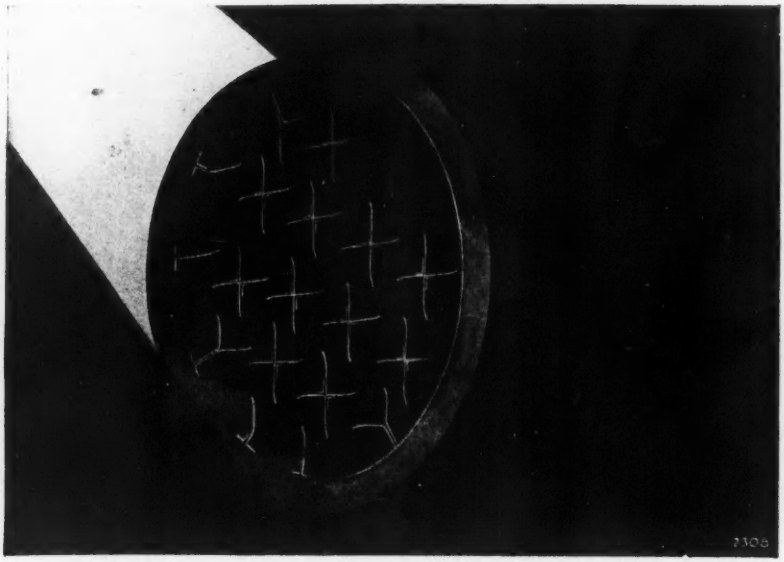

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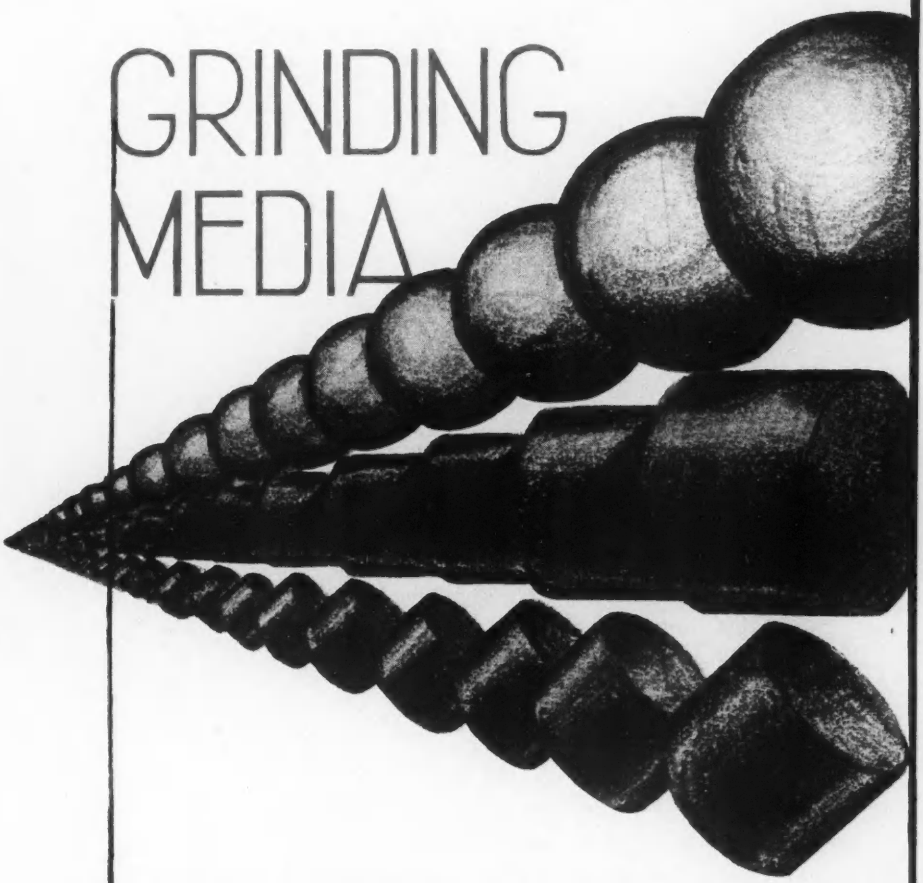

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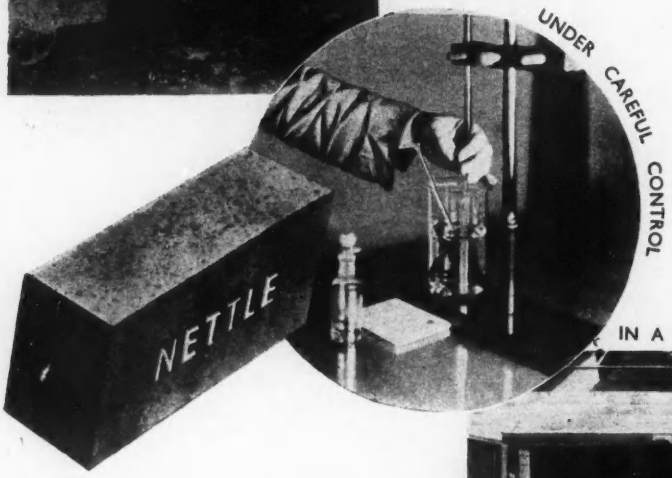

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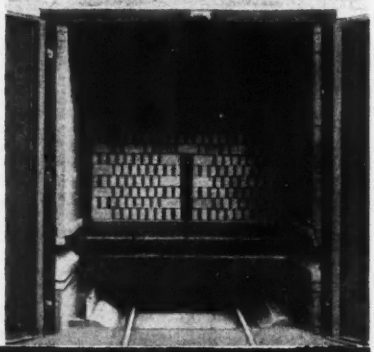

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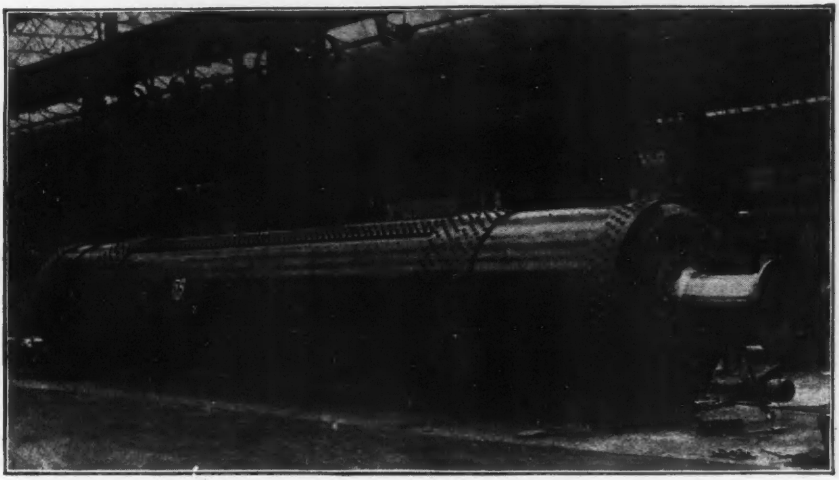

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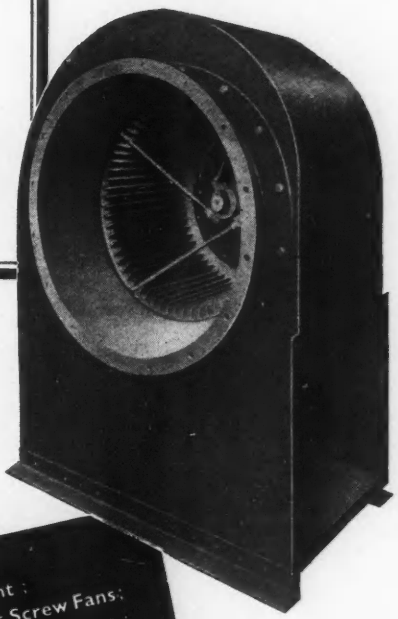

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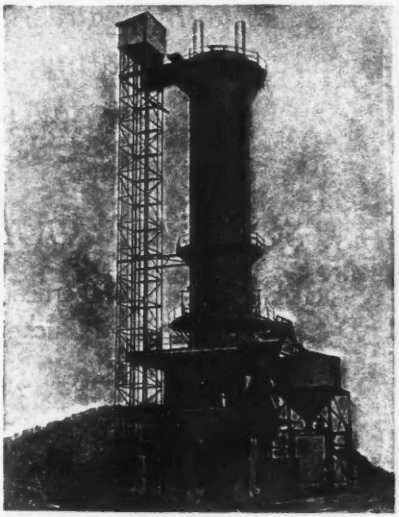

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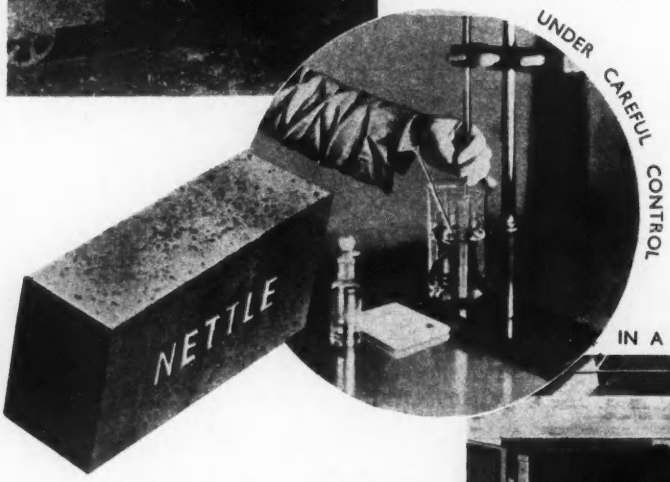

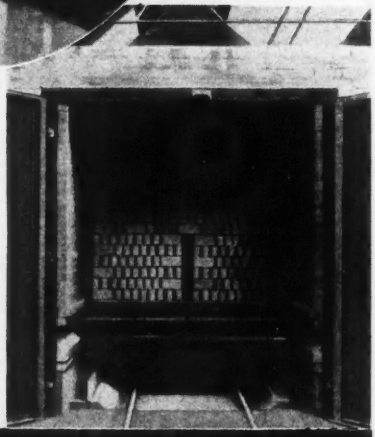

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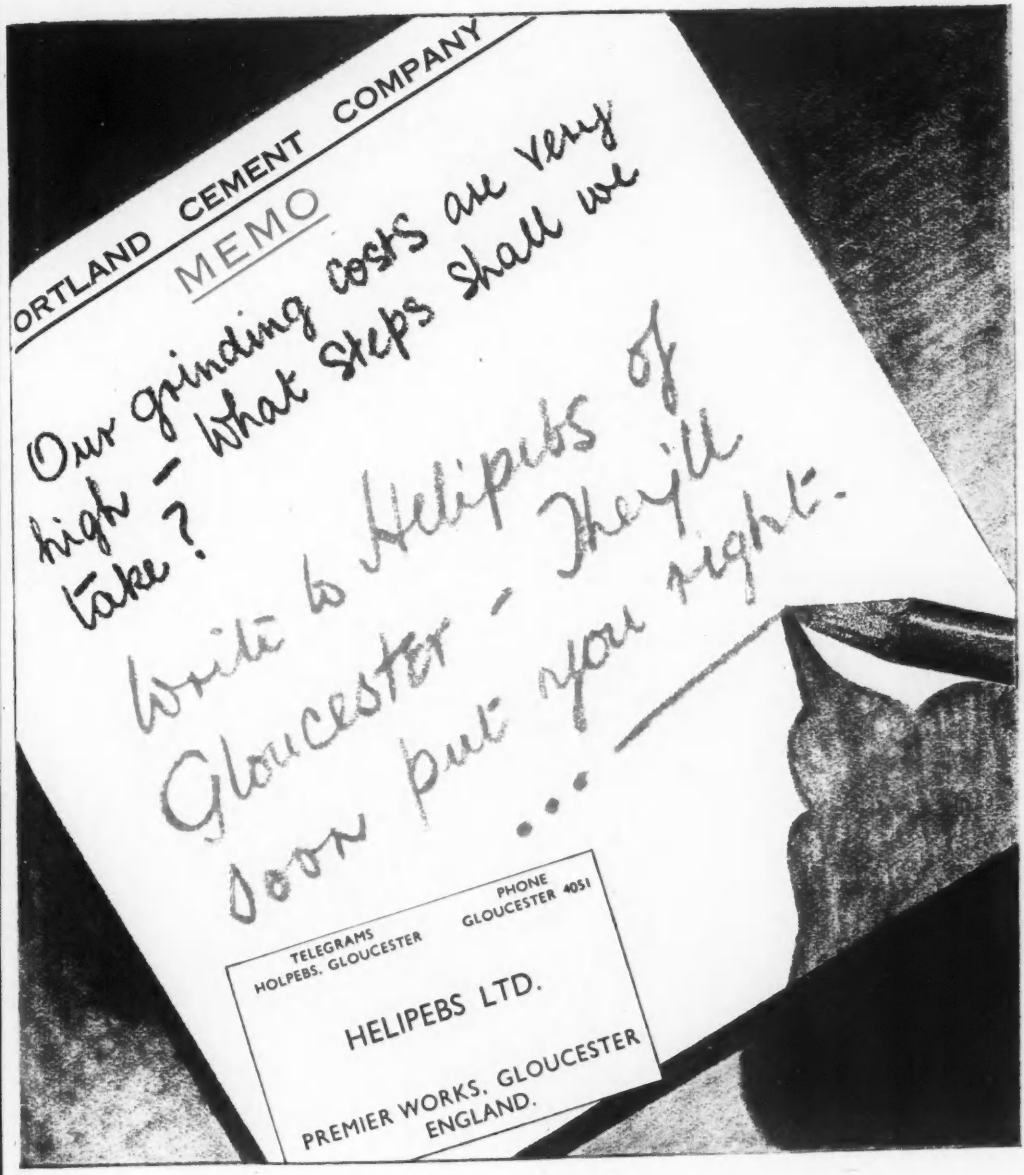
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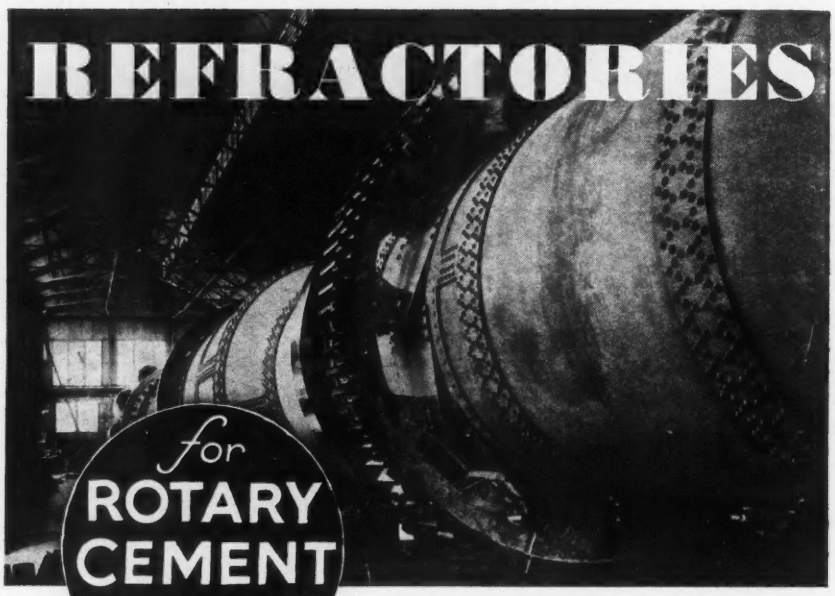

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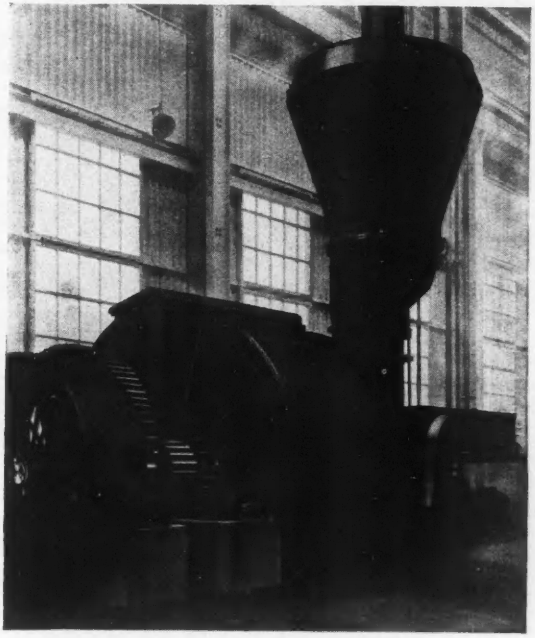

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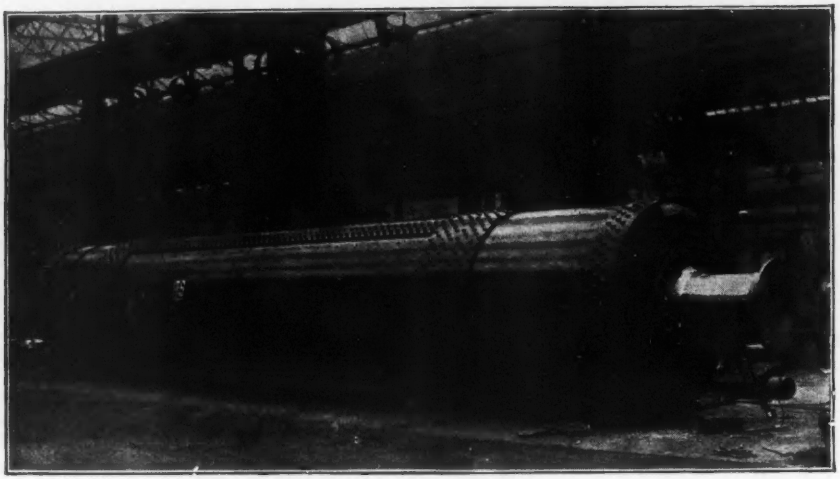

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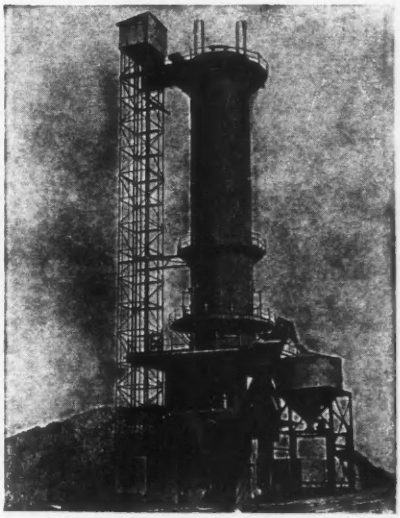

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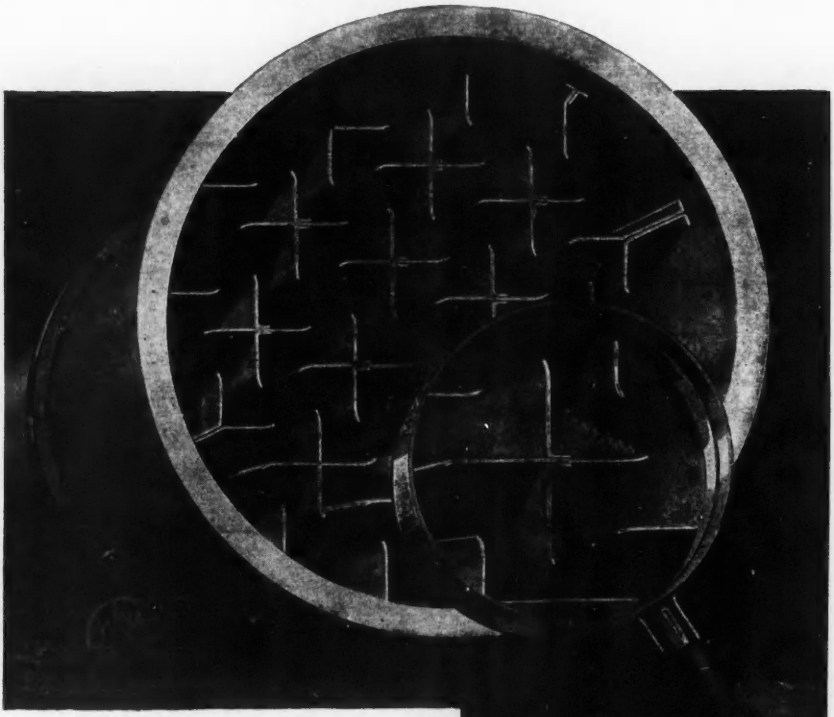

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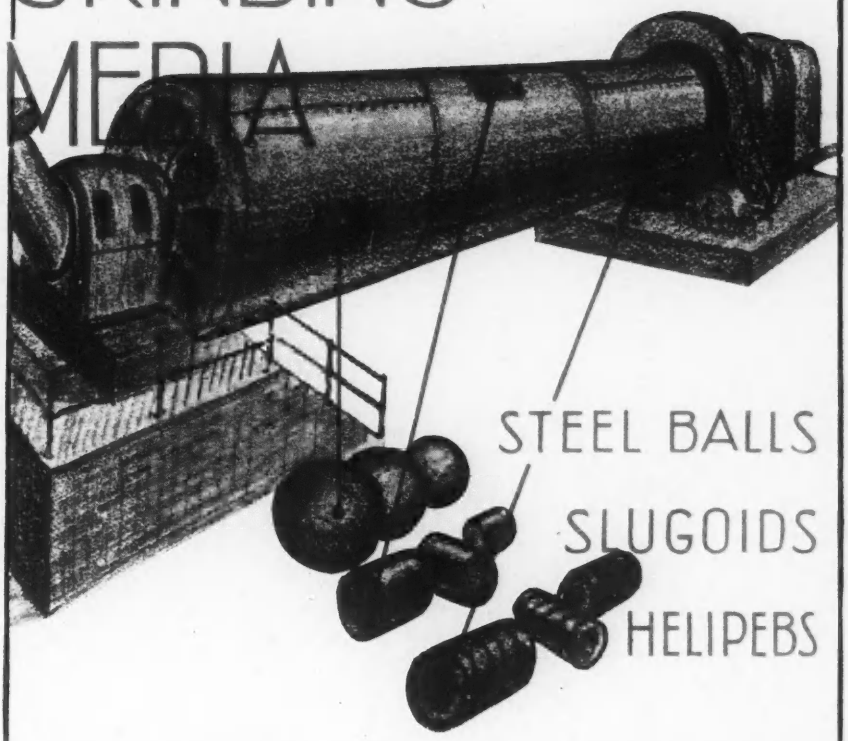

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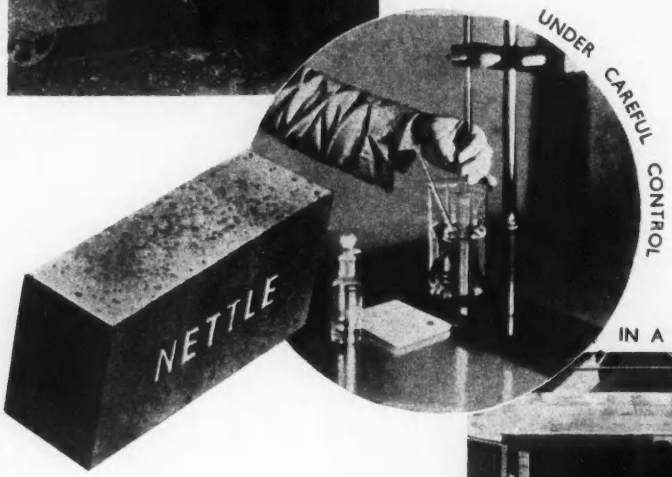

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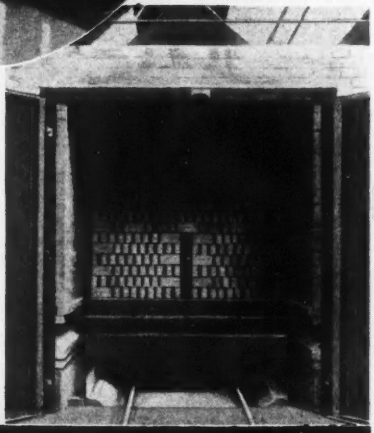

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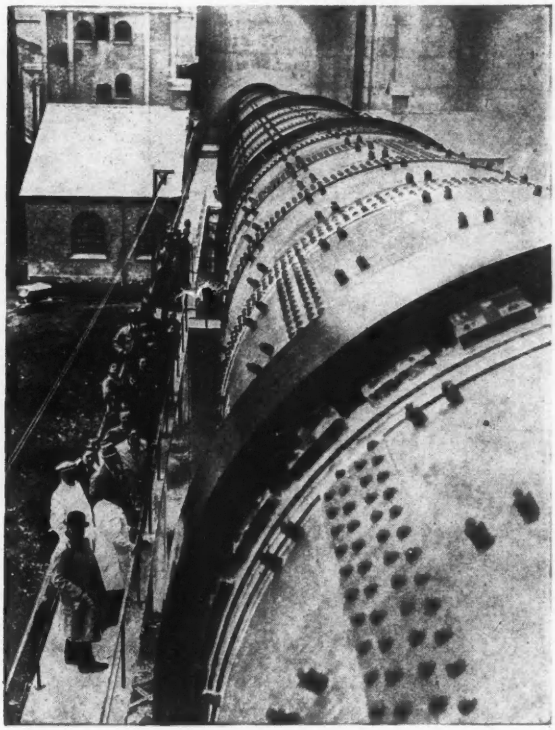

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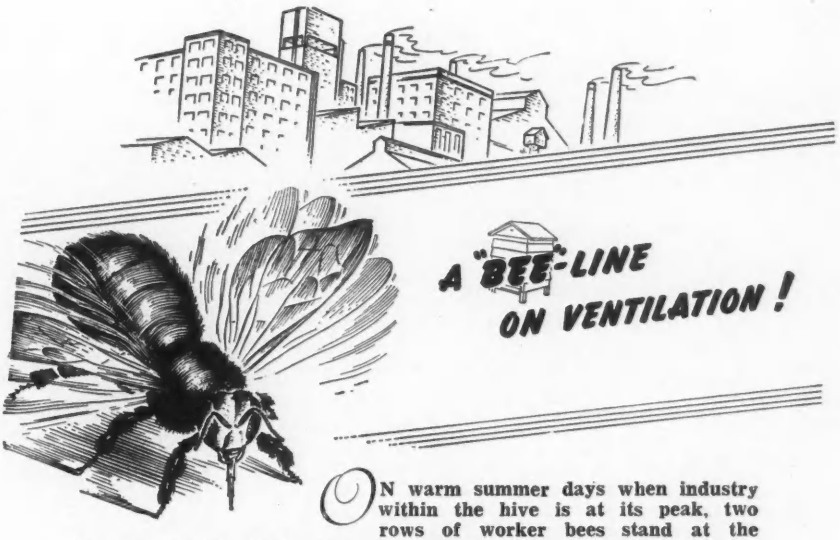

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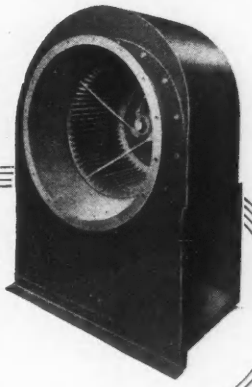

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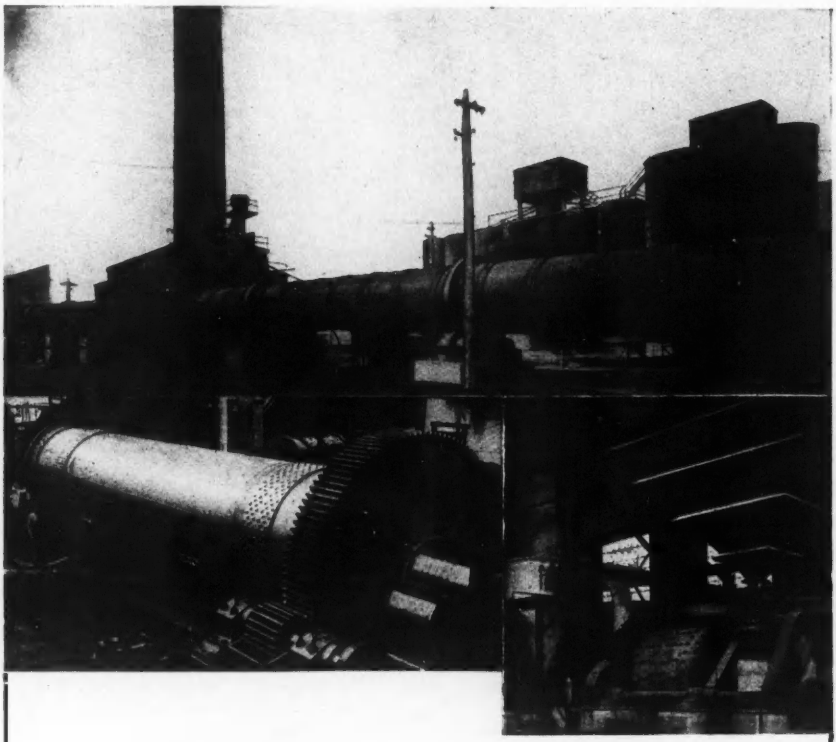

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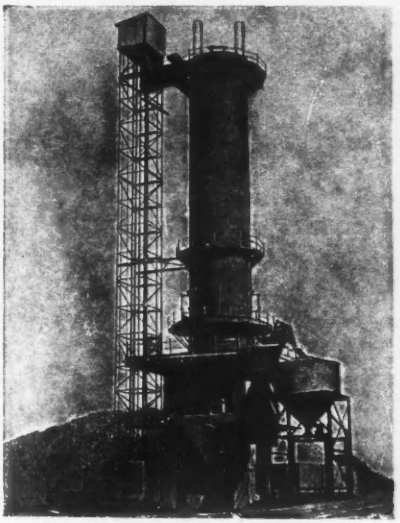

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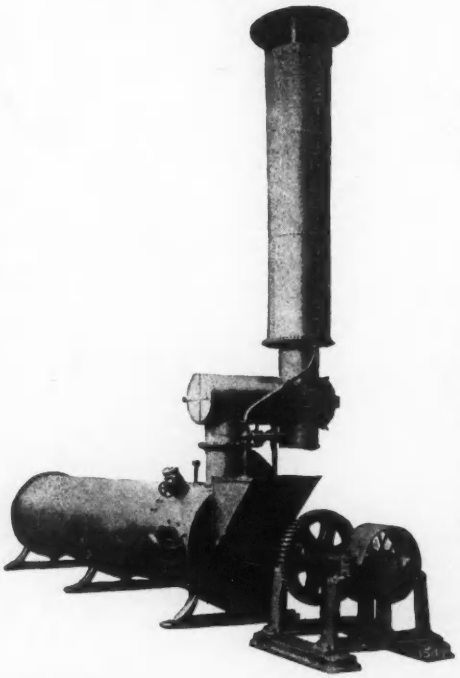

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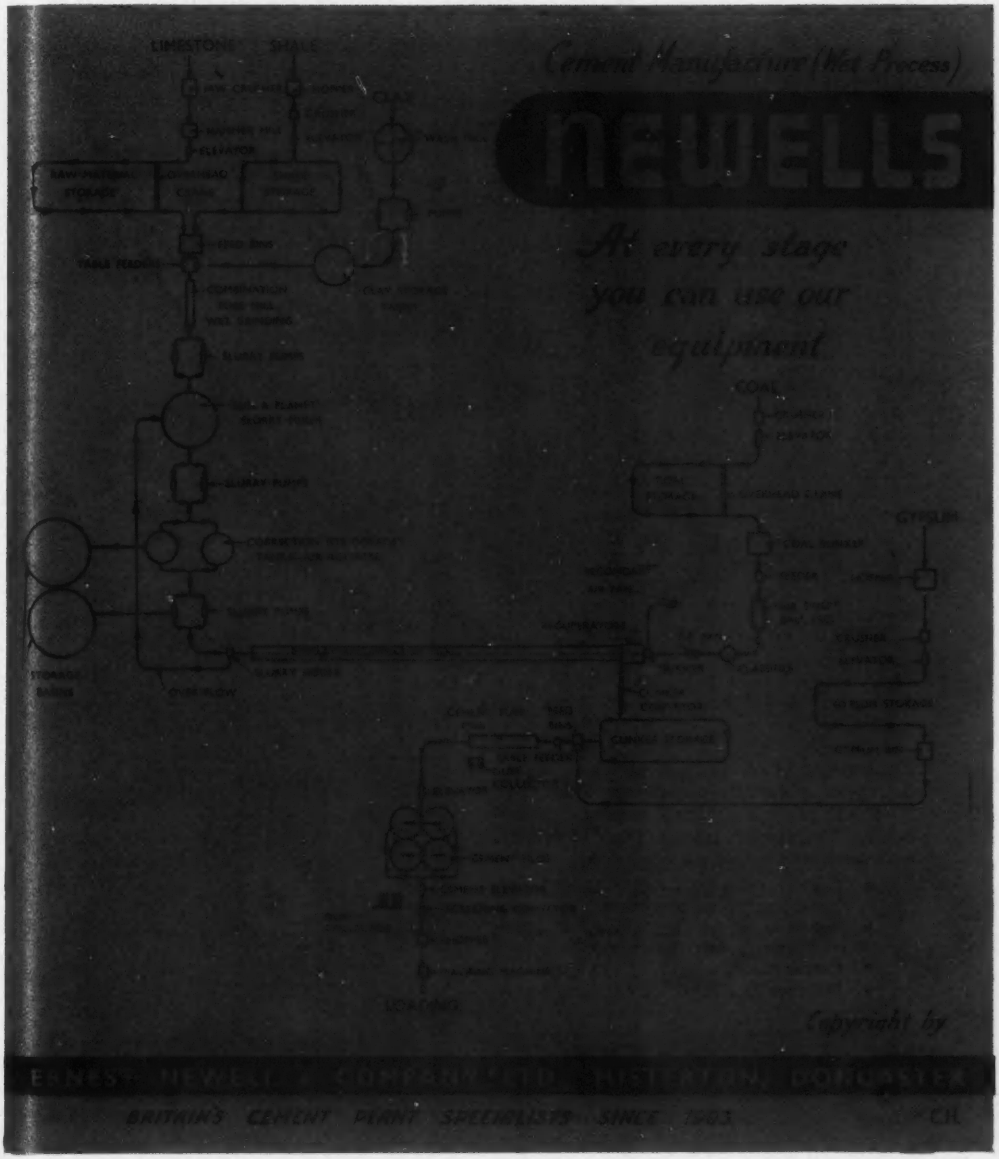

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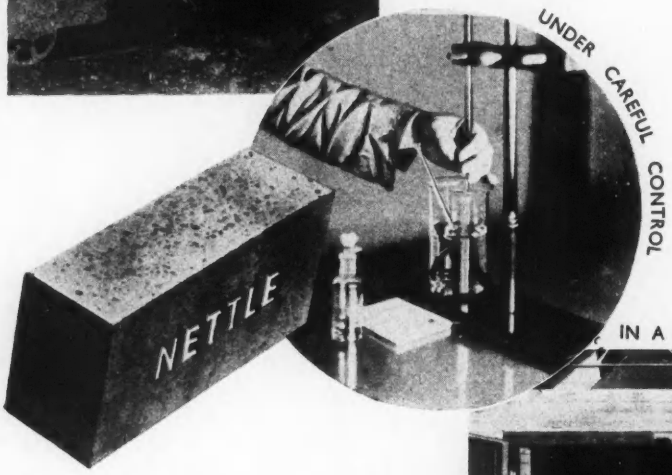

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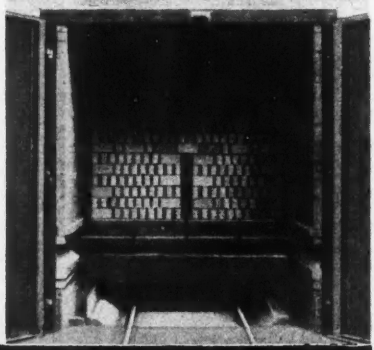

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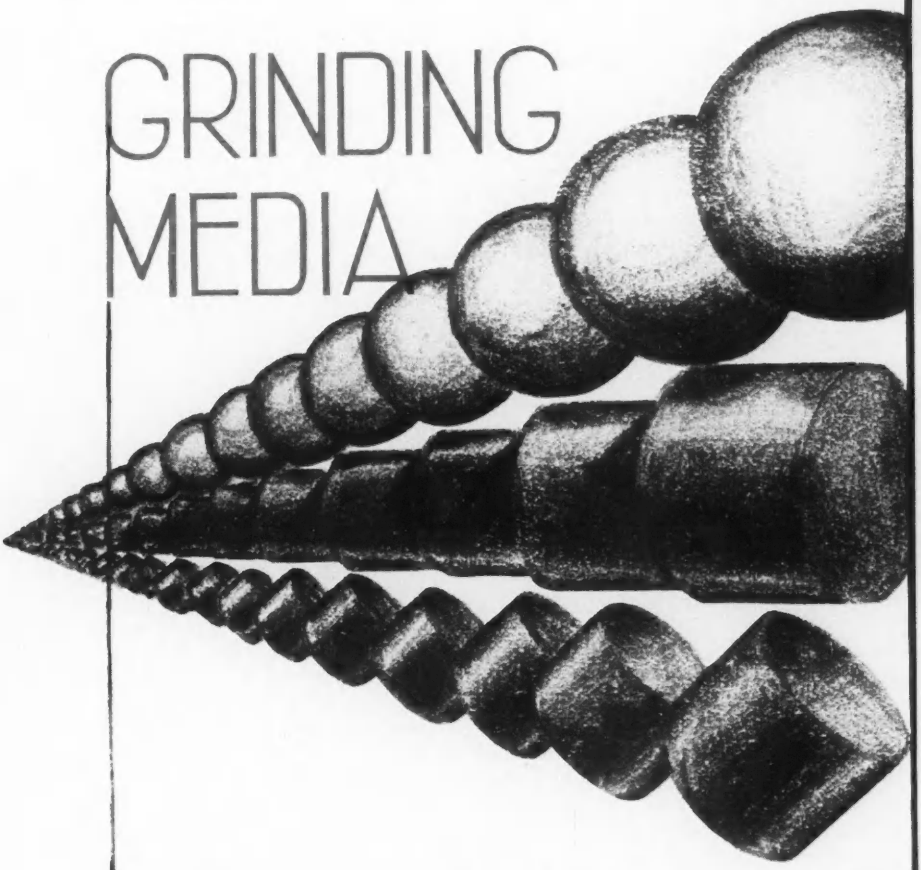

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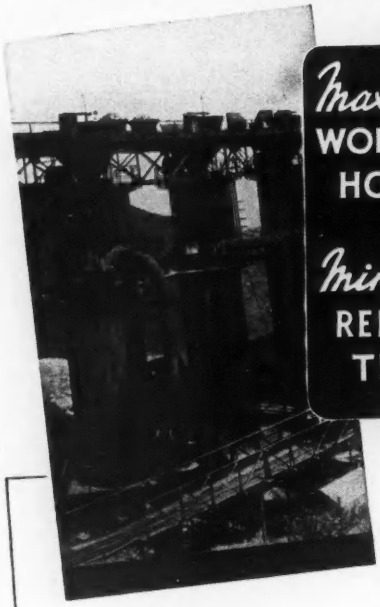

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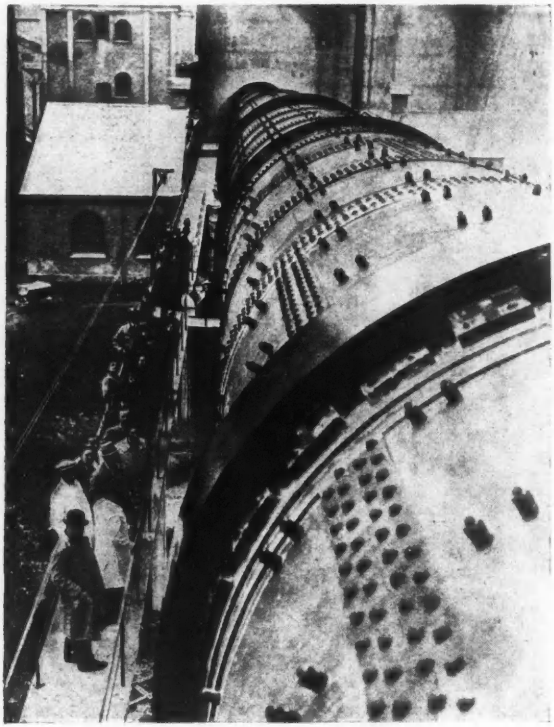

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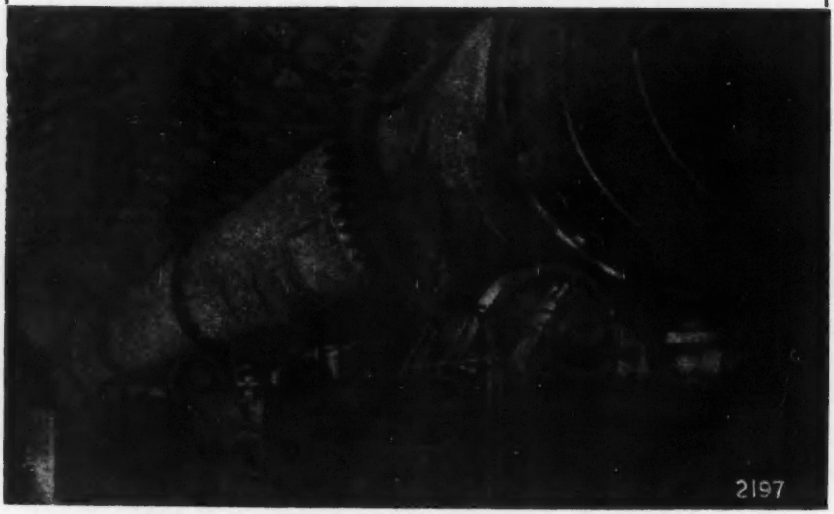

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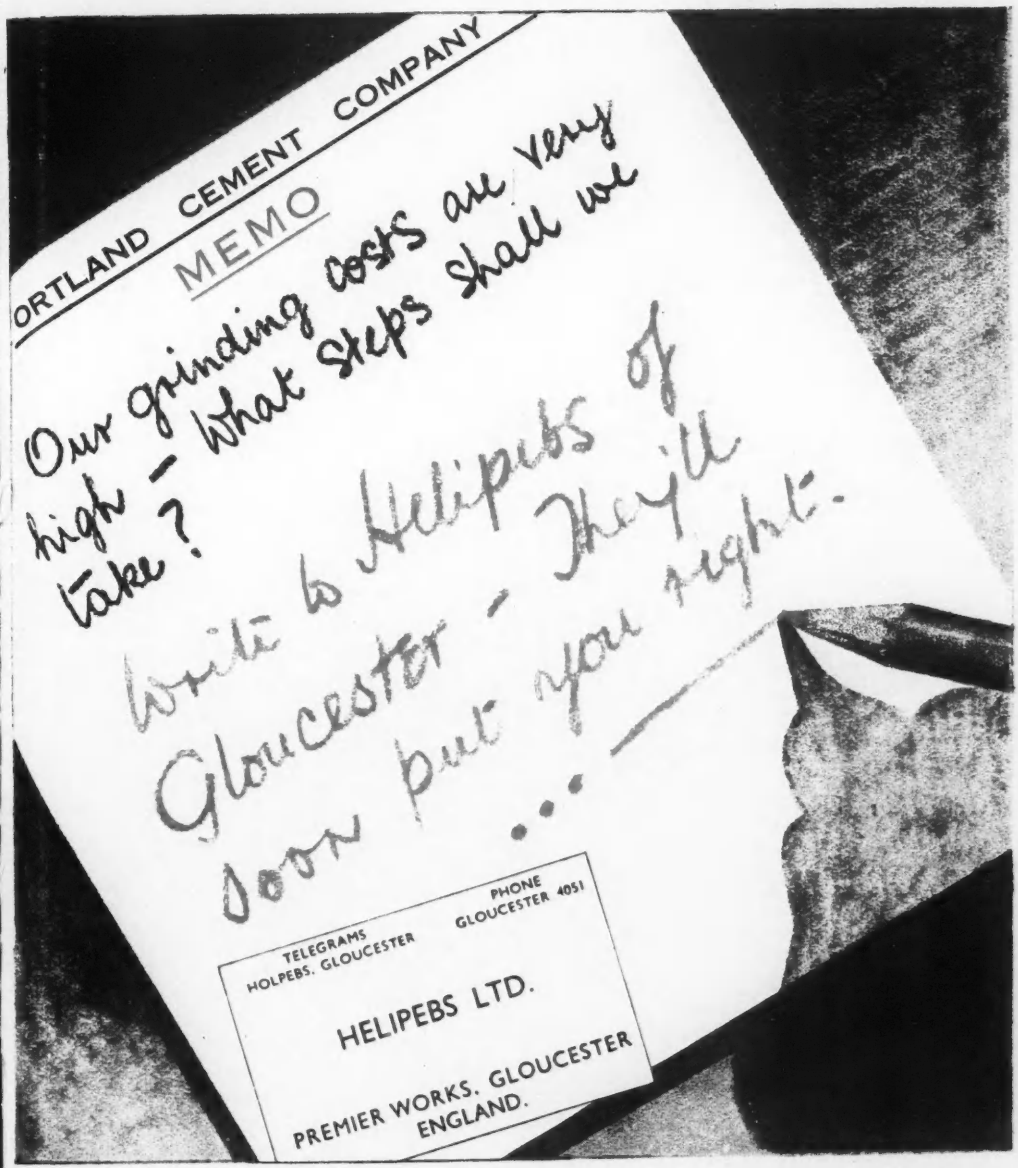
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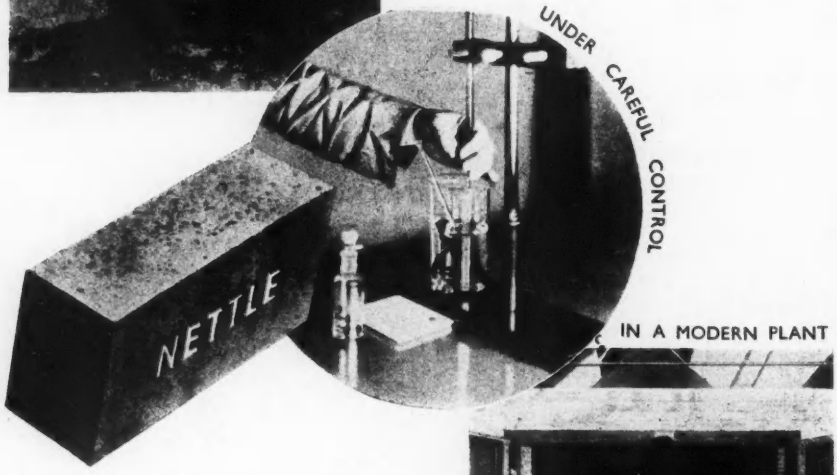

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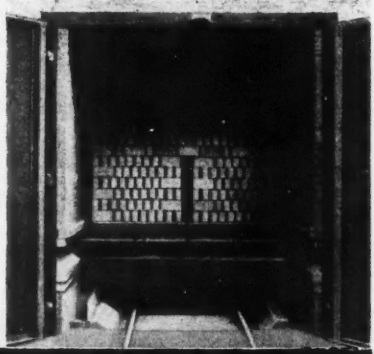

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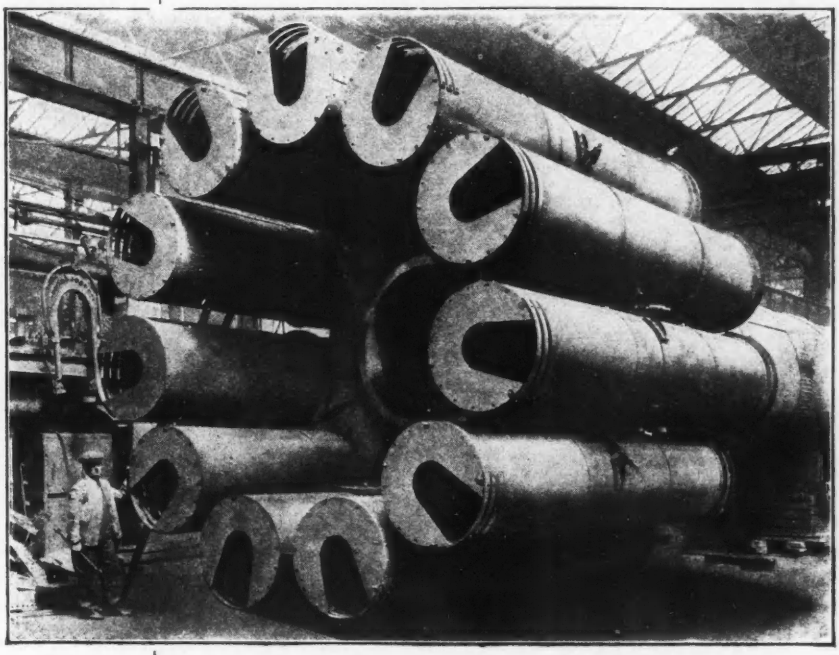

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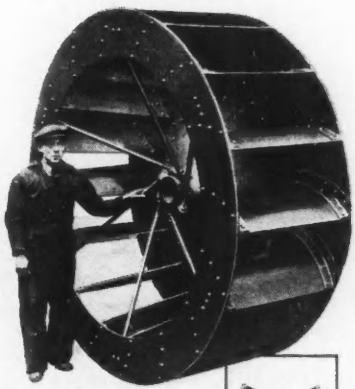

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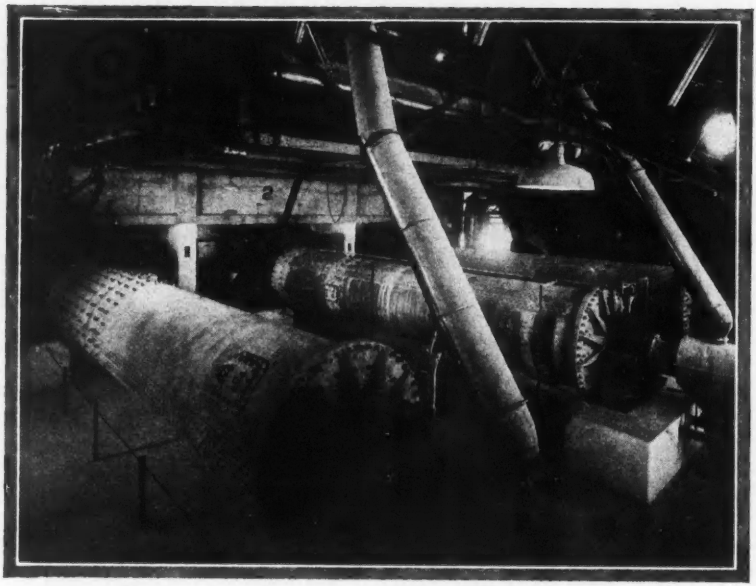

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FOR CALCINATION OF

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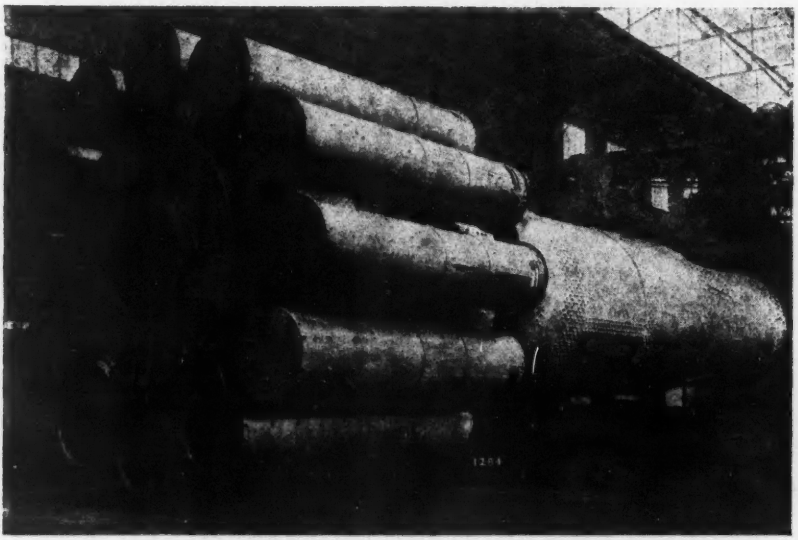

We illustrate here the well-known Tiger Rotary Kiln.

EDGAR ALLEN & CO. LTD., Imperial Steel Works, SHEFFIELD, 9

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